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(6) *Supersonic Transport Development Program.*

Phase III Proposal.

BOEING MODEL 2707.

Volume IV-1.

... COLOR PLATES: ALL ASTIA ... IN BLACK AND WHITE. ORIG... IN ASTIA HEADQUARTERS.

OPERATIONAL SUITABILITY,

(14) V4-B2707-1

(11) 6 Sep[redacted]66

(12) 356p.

(10) H. Betie

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FEDERAL AVIATION AGENCY

Office of Supersonic Transport Development Program

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FOREWORD

ENGINE AND AIRPLANE PERFORMANCE DATA

The engine and airplane performance provided in the main body of this document is based on engine performance data received prior to 15 July 1966.

The RFP provides for firm technical engine data to be submitted on 8 August 1966. The predicted effect of this data is of interest to the readers of this document. Accordingly, an addendum summarizing the effect of the 8 August 1966 engine performance on the B-2707 SST has been inserted into the following documents:

V2-B2707-3	Aerodynamic Design Report
V2-B2707-12	Propulsion Report - Part A
V4-B2707-1	Operational Suitability Report
V4-B2707-4	Airport and Community Noise Program

The performance information contained in the Summary document, the Model Specification, and the Statement of Work is based upon the 8 August 1966 firm technical data.

CONTENTS

B-2707 PHASE III PROPOSAL DOCUMENTATION INDEX

1.0 INTRODUCTION

Operational Suitability, the first in a series of 19 system integration documents, is prepared in response to Sec. 5 of the Request for Proposal for Phase III of the Supersonic Transport Development Program. This document presents the ~~B-2707~~ mission flexibility, environment integration reports, airport suitability summaries, and the operational integration plan for integrating the ~~B-2707~~ airplane and support equipment into airline service.

Figure 1-1 shows the relationship of this document to the other substantiating data which make up Vol. IV, System Integration. The other six operations documents include study and test reports concerning sonic boom, noise, safety, training, and human engineering. The test and simulation plans are contained in Documents V4-B2707-10 through V4-B2707-14. The third group, documents V4-B2707-15 through V4-B2707-20, consist of the Product Assurance Plans: Quality Assurance, Maintainability, Reliability, Value Engineering, Standardization, Product Support and Quality Control.

The suitability of the B-2707 design to meet, and in many instances exceed, its operational requirements is substantiated in the reports of Phase II studies and tests included herein.

The sections following this introduction are arranged to match the outline in the RFP and are applicable to both the intercontinental and domestic operation of the B-2707. Detail airport compatibility studies are limited to 15 designated domestic airports.

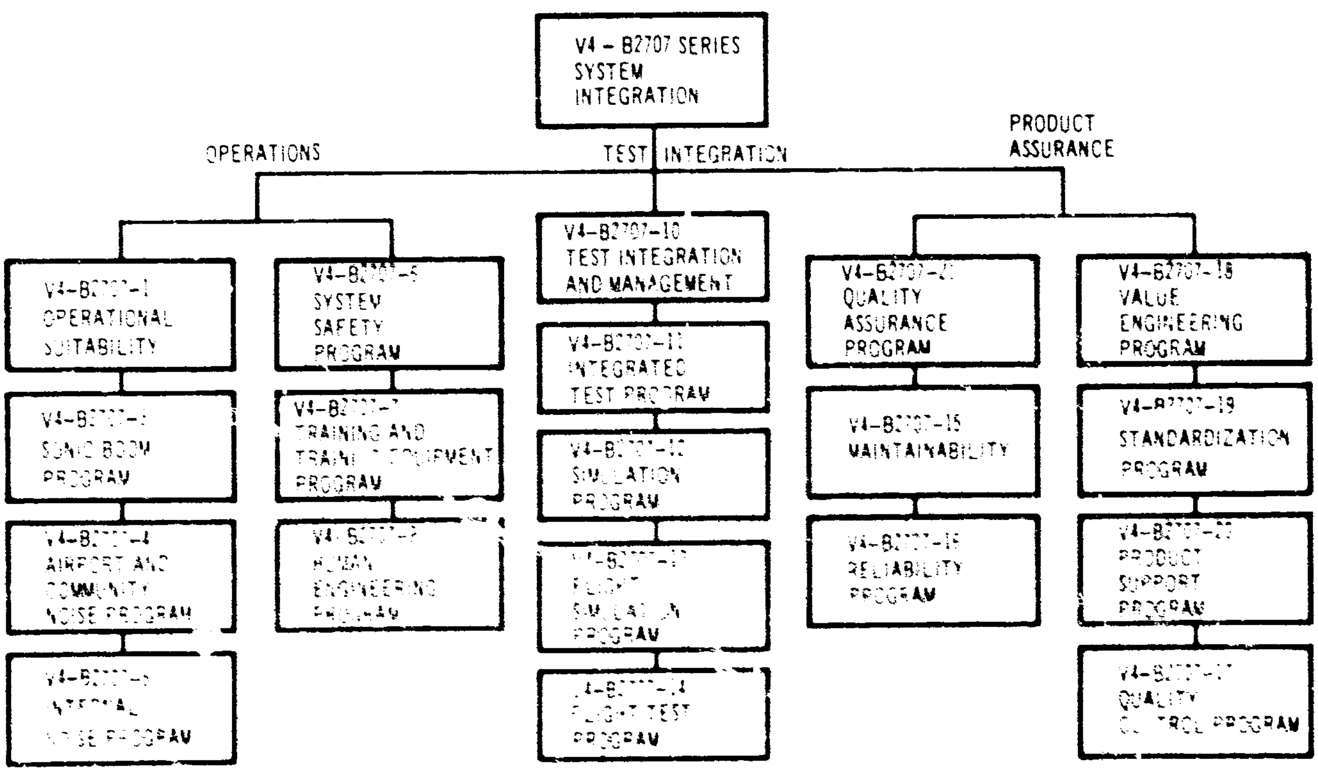

Figure 1-1. Volume IV System Integration Document Tree

The B-2707 (Fig. 1-2) is designed to carry a payload of 277 passengers approximately 4,400 statute miles at Mach 2.7 (3,819 nmi for GE and 3,738 nmi for P&WA). The B-2707 is comparable to, or exceeds the performance of, existing subsonic jets in takeoff and landing. Pertinent takeoff and landing characteristics are shown in Table 1-A. Because engine thrust is sized for transonic acceleration, the takeoff and climbout performance is exceptionally good. At 675,000 lb, the B-2707 FAR field length is 7,000 ft (GE) and 7,300 ft (P&WA). The B-2707 movable wing and the high thrust permits a wide selection of subsonic and supersonic speed schedules to satisfy the many different route structures and local considerations for noise abatement and sonic boom. Using noise abatement procedures, noise is reduced from 128 PNdb to 100 PNdb (GE) and 105 PNdb (P&WA) in communities below the airplane path at takeoff.

The takeoff and climb procedures are generally similar to current subsonic jets. Wing sweep management is an additional crew function; however, the engine operation requires significantly less management. Crew workload is comparable to current subsonic jet airplanes. This is accomplished by simplifying flight deck instrumentation and automating functions normally accomplished manually so that the crew can focus more attention on the manual tasks of flying the airplane.

For routes or legs where it is necessary to fly subsonically, the forward-wing position of the B-2707 offers a considerable economic advantage over the wings aft configuration. As shown in Table 1-B, the B-2707 can be operated subsonically at 42-degree sweep with no appreciable range penalty using the P&WA engine. Minor range loss occurs with use of the GE engine. Consequently, it is believed that the B-2707 is compatible with the domestic as well as intercontinental operations on a 24-hour-a-day basis.

Normal descent is comparable to present-day practice and the airplane has the capability of holding at lower altitudes subsonically without undue fuel penalty.

Fuel management procedures do not call for any fuel transfer to keep within center-of-gravity limits for normal operations as well as for unscheduled speed reductions or descent.

The following characteristics provide excellent landing capabilities:

- The wing sweep capability of 30 degrees and flaps 20/40-degrees down provide low landing speeds (144 kn), speed-thrust stability and low community noise levels (at 1 mi out 111 PNdb for GE, and 115 PNdb for P&WA.
- Forebody in the down position along with the low flight deck attitude provides visibility better than current jets.
- Engine acceleration characteristics are excellent, providing rapid thrust response during approach and reverse thrust operation on the ground.
- The high reverse thrust provides excellent stopping capability under adverse runway conditions.

Landing the B-2707 with wings swept aft (72 degrees) is similar to landing a subsonic jet with flaps retracted. The approach speed is 205 kn and the landing distance over a 50-ft obstacle is 6,000 ft when utilizing 4 engines in reverse thrust in a standard-day wet runway.

Sonic boom overpressure restrictions may have a significant influence on the operational profile of the B-2707. The trade between range and allowable sonic boom overpressure for the B-2707 is shown in Fig. 2-25 for three gross weights. These data are based on an all-supersonic mission; however, a subsonic leg prior to climb can be used to decrease the sonic boom overpressure at a given takeoff weight. Consequently, it is believed that the B-2707 has versatility to provide excellent domestic operational capability. For short-range flights, the B-2707 will perform an all-supersonic mission with a 2-psf overpressure. A substantial increase in range is available with a small increase in overpressure to 2.1 or 2.2 psf. For long-range flights, the B-2707 is operated subsonically over the first portion of a domestic route followed by a climb at 2-psf overpressure.

The B-2707, with its wings swept 72 degrees, has all the supersonic cruise advantages of the delta planform. The 72-degree wing sweep is

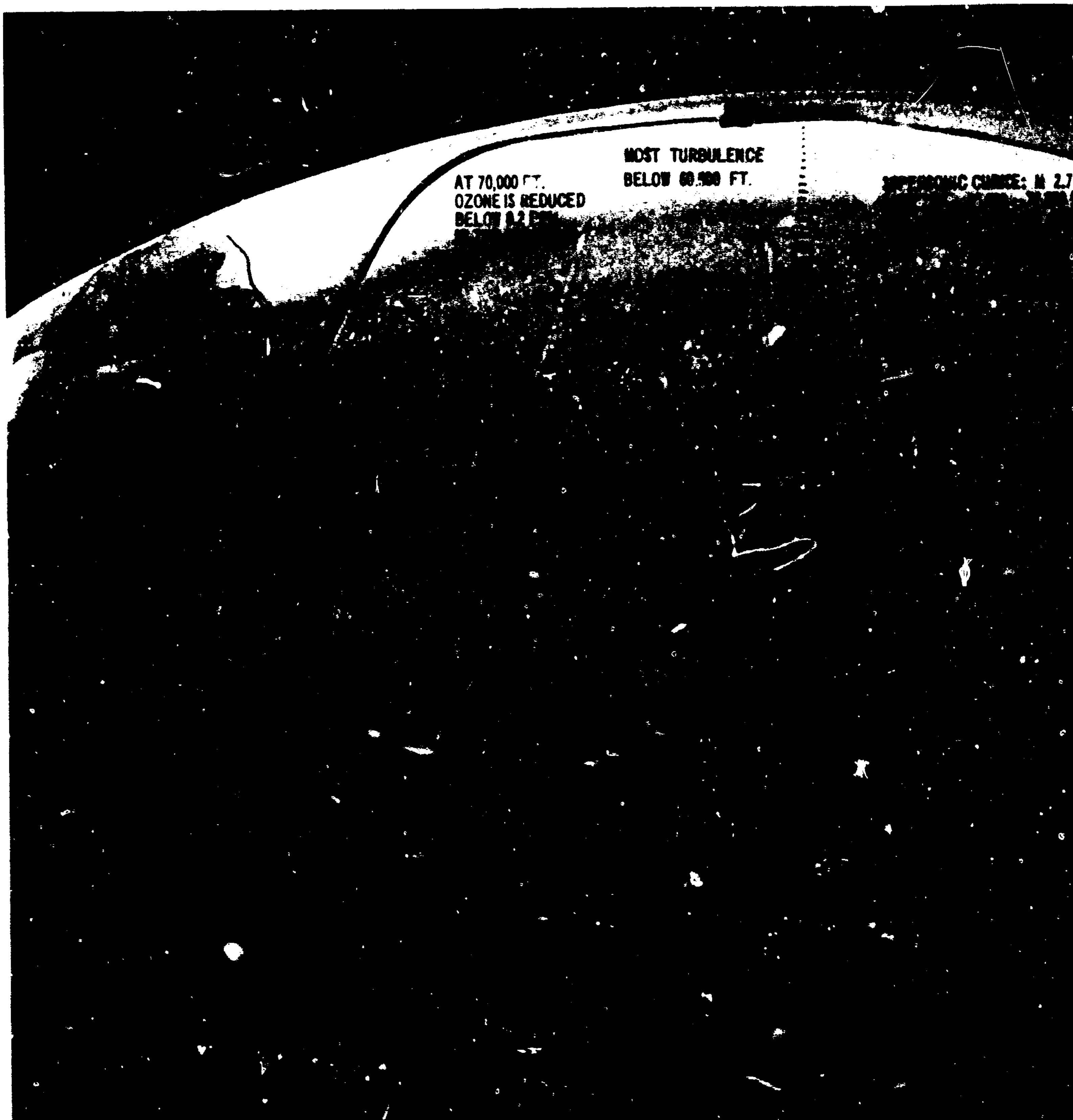

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Figure 1-2. B-2707 Operational Suitability

Table 1-A. Takeoff and Landing Characteristics

Model		B-2707 (GE)	B-2707 (P&WA)	B-707-320
Takeoff weight, lb		675,000	675,000	334,000
Landing weight, lb		384,000	378,000	215,000
FAR takeoff field length, ft		7,000	7,300	11,050
Takeoff speed (liftoff), kn		169	169	165
Takeoff noise, PNdb, at 3 mi from brake release		100	105	120
Approach speed, kn	Noise abatement Procedure	133	131	137
Landing approach noise, PNdb at 1 mi from threshold	Noise abatement Procedure	108	111	122
FAR landing field length, ft	Noise abatement Procedure	6,280	6,220	6,060
Approach speed, kn	Flaps 20/40 degrees	144	143	-
Landing approach noise, PNdb at 1 mi from threshold	Flaps 20/40 degrees	111	115	-
FAR landing field length ft	Flaps 20/40 degrees	6,900	6,850	-
Engine acceleration response time, seconds (idle to 95 percent dry power)		4	6	7

significant in its capability to penetrate turbulence without undue discomfort for the passengers. Unlike the B-70, which has canard surfaces, the B-2707 exhibits small acceleration from gusts. This favorable response is largely attributed to the wing sweep of 72 degrees, the flexibility of the fuselage structure, and the higher wing loading made possible by the variable-sweep concept. In addition, cruising at 60,000 to 70,000 ft greatly reduces the average intensity and frequency of turbulence encounters when compared to current airline jets operating at altitudes of 35,000 ft.

Ozone concentrations are reduced to within the tolerable level of 0.2 ppm (by volume). Ozone reduction is accomplished by the combined effects of the high initial temperatures of the intake air and the catalytic action of nickel plating in the environmental control equipment.

Solar radiation is filtered to a tolerable level largely by the atmosphere above the B-2707 cruise altitudes with additional filtering accomplished by the airframe. The dosage from the current level of radioactive particles is negligible because of the inherent filtering action of the air-conditioning system.

Table 1-8. Change in Total Range Capability

Mission Description	B-2707 (GE)	B-2707 (P&WA)
Total mission supersonic	3,819 nmi	3,738 nmi
400 nmi subsonic leg at beginning of mission	-63 nmi	No loss
400 nmi subsonic leg at end of mission	-104 nmi	- 40 nmi
Total mission subsonic	-533 nmi	+132 nmi

3786

A passenger cabin window blowout (33.2 sq in.) at 70,000 ft is not catastrophic because the cabin pressure altitude is maintained within safe limits. With three of four air conditioning packs operating, the cabin pressure is held to 7,000-ft altitude pressure.

The B-2707 is compatible with the National Airspace System, with consideration for the projected improvements. The inertial navigation subsystem (INS) enables the B-2707 to fly on-course or on parallel courses in order to lessen sonic boom exposure. The self-sufficiency of the INS provides the captain with positive navigation references at all times during worldwide operations. The airplane is also equipped with an automatic landing system to permit operations at airports with visibility as low as 700 ft. The other basic communication/navigation equipments are the VHF, Omni-Range system (VORTAC), an ATC transponder, HF radio, LORAN (optional), ILS, weather radar, ADF, radio altimeter, interphone system, and public address system (Figs. 1-3 and 1-4).

Safety has been emphasized in the design of the B-2707 to achieve safety levels in excess of current standards. The design considerations for

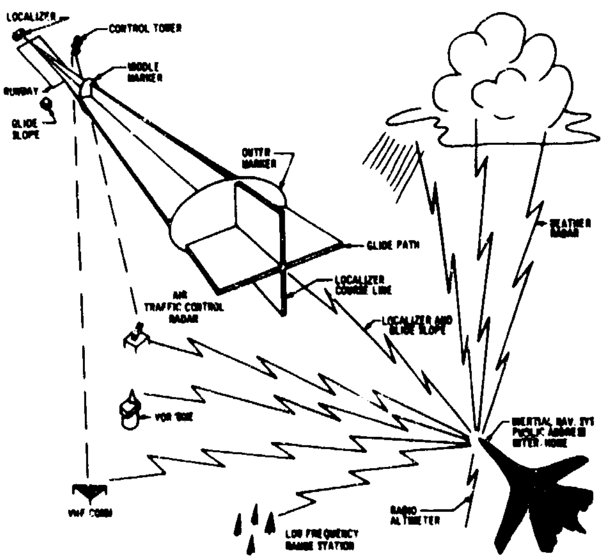


Figure 1-3. Comm/Nav Equipment Used in Terminal Area Operation

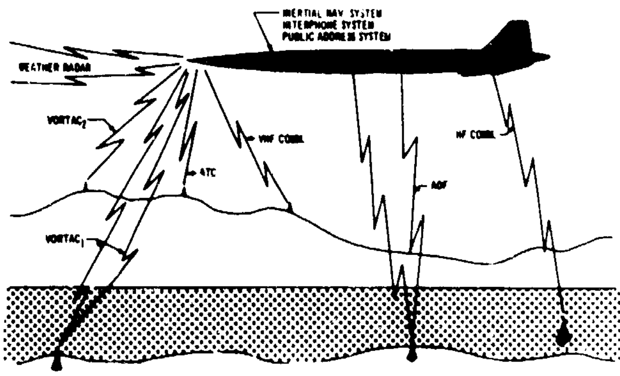


Figure 1-4. Comm/Nav Equipment Used During Cruise

Table 1-C. Ground Heading and Support

	B-2707 min	B-707-320 min
Turnaround time	30	90
Enroute time	20	30
Cleaning (turnaround)	14	26
Cargo handling (load) } turnaround	12	6
Cargo handling (unload) } turnaround	11	7
Cargo handling (load-enroute)	6	4
Cargo handling (enroute unload)	6	5
Enroute fueling	16	16
Turnaround fueling	23	18
Ground engine starting	2	2

safety are discussed in the System Engineering Report, V2-B2707-1, and the proposed safety program during Phase III is presented in the System Safety Plan, V4-B2707-6.

Although the B-2707 performance is significantly different from current subsonic jets, the basic ground handling and servicing procedures and equipment are similar. Ground operations have been reduced by careful consideration of the handling and servicing features of the airplane (Table 1-C). Significant improvement over current operation is provided by the airborne integrated data system (optional equipment), which reduces investigation time and provides ground crews with specific advance information on inoperative units. (Refer to Par. 3.7 of this document for details.)

The forward door sill height is compatible with existing passenger handling equipment. Using only the two forward doors, 277 passengers can deplane in 8 minutes; the 707/DC-8 unloads 139 passengers in 5 minutes. For faster loading and unloading, the aft doors can be used, but such use requires modified ground equipment to bridge over the wing/stabilizer structures.

Maintainability of the B-2707 will be comparable to current jets. The maintenance concept is built around experience gained on the current 707/720/727 series and places more emphasis on subsystem self-test capability.

The overall compatibility of the B-2707 with current and planned airports is excellent. Continuing improvements and expansion programs at the world's airports to keep pace with air traffic growth will provide an airport network into which the B-2707 can be introduced without significant need for major investments. The landing gear loads are distributed through a four-wheel four-truck system. At 675,000 lb, the B-2707 requires a pavement depth very similar to that required by existing heavy jet airplanes, such as the DC-8-55. Consequently, the B-2707 is generally compatible with existing runways. This subject is treated in greater detail in Sec. 4.0 (Airport Suitability Report).

Transition training for pilots is minimized by B-2707 similarities to current subsonic jets in takeoff and landing and handling qualities. Ground crew training is required although many of the subsystems are similar to those of existing jets,

and maintainability has been improved. Current flight crew training techniques and methods, which have recently been updated to place increased emphasis on simulators, have been adopted and improved for the B-2707 (Training and Training Equipment Program, V4-B2707-7).

Noise suppression equipment, a high-span wing to reduce thrust requirements, and tailoring of operational procedures have been employed to minimize noise levels at airports and neighboring communities throughout the takeoff and low altitude flight regime. (See Par. 2.5.2 of this document and the Airport and Community Noise Program, V4-B2707-4 for details.)

Noise levels during taxi and ramp operations are comparable to present-day subsonic jets. Maintenance run up at high powers may require ground suppressors. Current technology can provide adequate ground run up suppressors to achieve the required noise reduction.

The three most noise-critical periods of flight for cabin noise are takeoff, transonic acceleration, and cruise. The overall sound pressure and the speech interference levels predicted for each of these flight conditions do not exceed the design criteria and are lower than the noise levels occurring during similar type operations with current subsonic jets.

During succeeding program phases, actions are planned to demonstrate satisfactory integration of the B-2707 into its complete operating environment. Section 5.0 (Operational Integration Program) identifies the necessary activities leading to an operational airplane. These are in terms of its mission flexibility, environment integration, noise, sonic boom, safety, and human engineering considerations. The ground handling and support and training programs detailed in other sections of the proposal are summarized as they are germane to supporting the operational integration of the airplane. Study of the airports and operational facilities will continue well into the program in order to provide the basis for modifications and new construction in time to meet the operational needs of the B-2707.

CONTENTS

2.0 MISSION FLEXIBILITY

2.1 INTRODUCTION

The B-2707 is adaptable to the wide variety of airline operational conditions presently encountered, as well as those envisioned for the next decade. This section describes the normal and off-design operation of the airplane and the abnormal and emergency conditions. The capability of the airplane to operate efficiently over domestic routes with lower sonic boom overpressures, as well as over the intercontinental routes is discussed. The flight crew equipment and procedures are developed from careful analysis, close liaison with F-12 and B-70 flight crews, and simulator studies of various segments of the flight profile. Airline flight crews are being continuously consulted in order to ensure compatibility of the ground handling and flight characteristics of the airplane with the airline flight crews and operational environment. Certain instrumentation, controls, and visibility features are described.

The B-2707 mission flexibility and performance described in this document is based on the General Electric engine. Where a significant difference in the airplanes performance results from the use of the Pratt and Whitney engine, that difference is discussed. The B-2707 performance data using these engines is contained in Airplane Performance, V2-B2707-4 (GE), and Airplane Performance, V2-B2707-5 (P&WA).

The passenger and cargo compartments are structured to permit significant flexibility in configuration. This flexibility consideration is discussed in Airframe Design Report, Part B, V2-B2707-6-2.

2.2 FLIGHT PLANNING

A major item in planning a flight is the fuel requirements. The total fuel required is affected significantly by small variations in air temperature. Paragraph 2.6.1 discusses this effect and provides fuel requirements for specific flights. A pre-computed fuel usage schedule ("how goes it") will be used by the flight crew to compare with the actual fuel consumed. Figure 2-1 shows the fuel tank arrangement and tank capacities. For normal operations a single fuel loading procedure will maintain the airplane cg within limits. If the payload distribution is markedly different from that expected at the time of refueling, transfer of fuel between the forward and aft auxiliary tanks may be performed to improve the airplane's trim drag characteristics. The time required for the maximum possible auxiliary fuel tank transfer on the ground or in flight is approximately 10 minutes. For lower payloads and training flights, restricted seating and/or ballast may be required. A water ballast tank located in a pressurized compartment forward of the nose gear is provided for flexible cg control.

The amount of fuel to be loaded is based on range. The fuel loading chart specifies the fuel quantity to be loaded in each tank (Figure 2-2).

Another aspect of flight planning is the departure routing and ground track during transonic acceleration. The sonic boom effects over populated areas can be minimized by varying the ground track during transonic acceleration by departing over sparsely populated areas. In addition, the efficient subsonic capability of the B-2707 can be used to eliminate sonic boom effects on critical areas. Subsonic performance data is shown in Pars. 2.6.2 and 2.6.3.

The navigation enroute is relatively simple in that the largest portion of the flight will be a straight line with a minimum of heading changes. The inertial navigation system provides flexibility such as parallel tracking, multiple departure and arrival "canned" routing.

2.3 TAXI

The maximum taxi gross weight is 675,000 lb. The taxiing technique is similar to that used for large subsonic jet transports. Steering is accomplished with hand wheels located outboard of both pilots. Nose-wheel steering of ±5 deg is obtainable with the rudder pedals for use primarily during takeoff and landing.

2.3.1 Steering Capability and Limits

The minimum turning radius of the airplane occurs at 76 deg nose-gear steering. At this angle the nose gear sweeps an arc of 119 ft radius and the nose, an arc of 199 ft. A 180-deg turn can be

made on a 200-ft-wide runway with the main and nose gear having at least 20 ft of pavement edge margin.

The longer wheel base has been analyzed as to airport ramp, taxiway, and runway compatibility at certain existing international airports. It has been established that the airplane can be maneuvered safely on these facilities. (See Sec. 4.0.)

2.3.2 Pilots Position with Reference to Landing Gear and Height Above Runway

The pilots are located 185 ft ahead of the aft main landing gear, 54 ft ahead of the nose gear, and 18 ft above the runway. The corresponding distances on a 707-300 series airplane are 70 ft ahead of the main landing gear, 11 ft ahead of the nose gear and 14 ft above the runway.

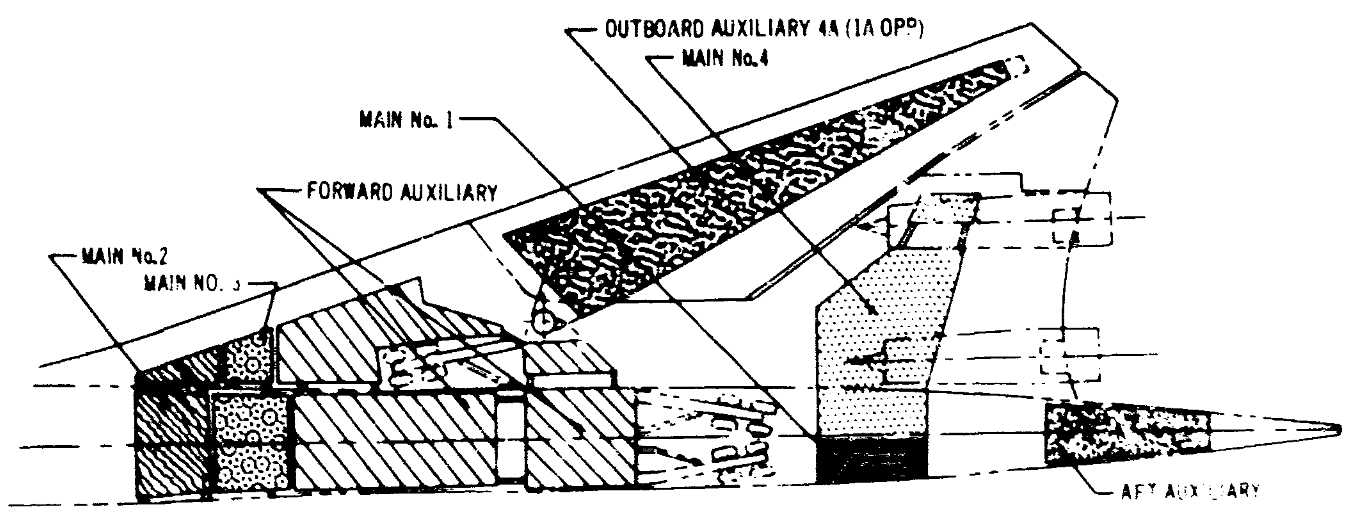
The normal taxi configuration will be with the forebody full-down and wing-sweep position set at 30 deg. In this configuration the pilots will see both wingtips and can see the ground 43 ft in front of the airplane as compared to 51 ft for subsonic jets.

Closed circuit television may be used to assist the pilot in ground maneuvering. By use of this system, the pilot can monitor the tracking and clearances of the landing gears. The need and effectiveness of this system will be demonstrated on the prototype airplane. A similar type television system has been flight tested by the company on a 707-320 and found to be practical for ground operations. Figure 2-3 illustrates such an application of TV.

Pilot visibility is discussed in Par. 2.11.

2.3.3 Taxi Thrust

The idle thrust for taxiing on current fan jet transports results in frequent braking, expecially at medium and light weights, to maintain safe taxi speeds. A low idle thrust setting has been incorporated on the B-2707 to reduce the thrust and fuel flow during taxi and ground hold opera-



TANK	FUEL GALLONS	FUEL POUNDS
MAIN No. 1	4,150	27,800
MAIN No. 2	4,150	27,800
MAIN No. 3	4,150	27,800
MAIN No. 4	4,150	27,800
FORWARD AUXILIARY	20,450	137,000
AFT AUXILIARY	3,820	25,600
OUTBOARD AUXILIARY 1A	7,530	50,450
OUTBOARD AUXILIARY 4A	7,530	50,450
TOTAL CAPACITY	55,930	374,700

THE EXCESS VOLUME IN THE AFT AUXILIARY IS USABLE AT THE OPERATOR'S OPTION TO OPTIMIZE CRUISE CENTER OF GRAVITY FOR HIGH PAYLOADS

NOTE: MAXIMUM USABLE FUEL [illegible] POUNDS

Figure 2-1. Fuel Tank Arrangement

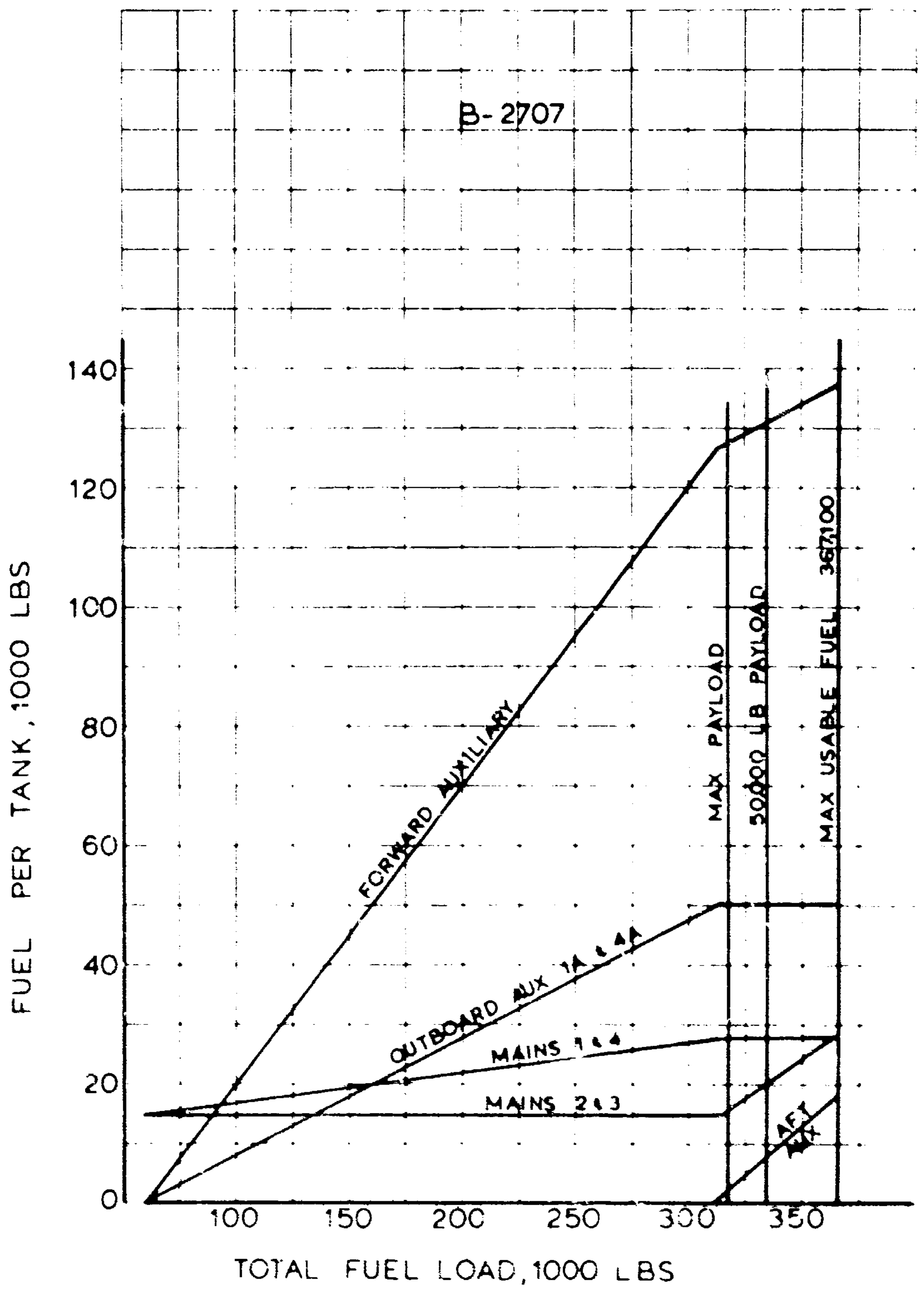


Figure 2-2. Fuel Loading Chart

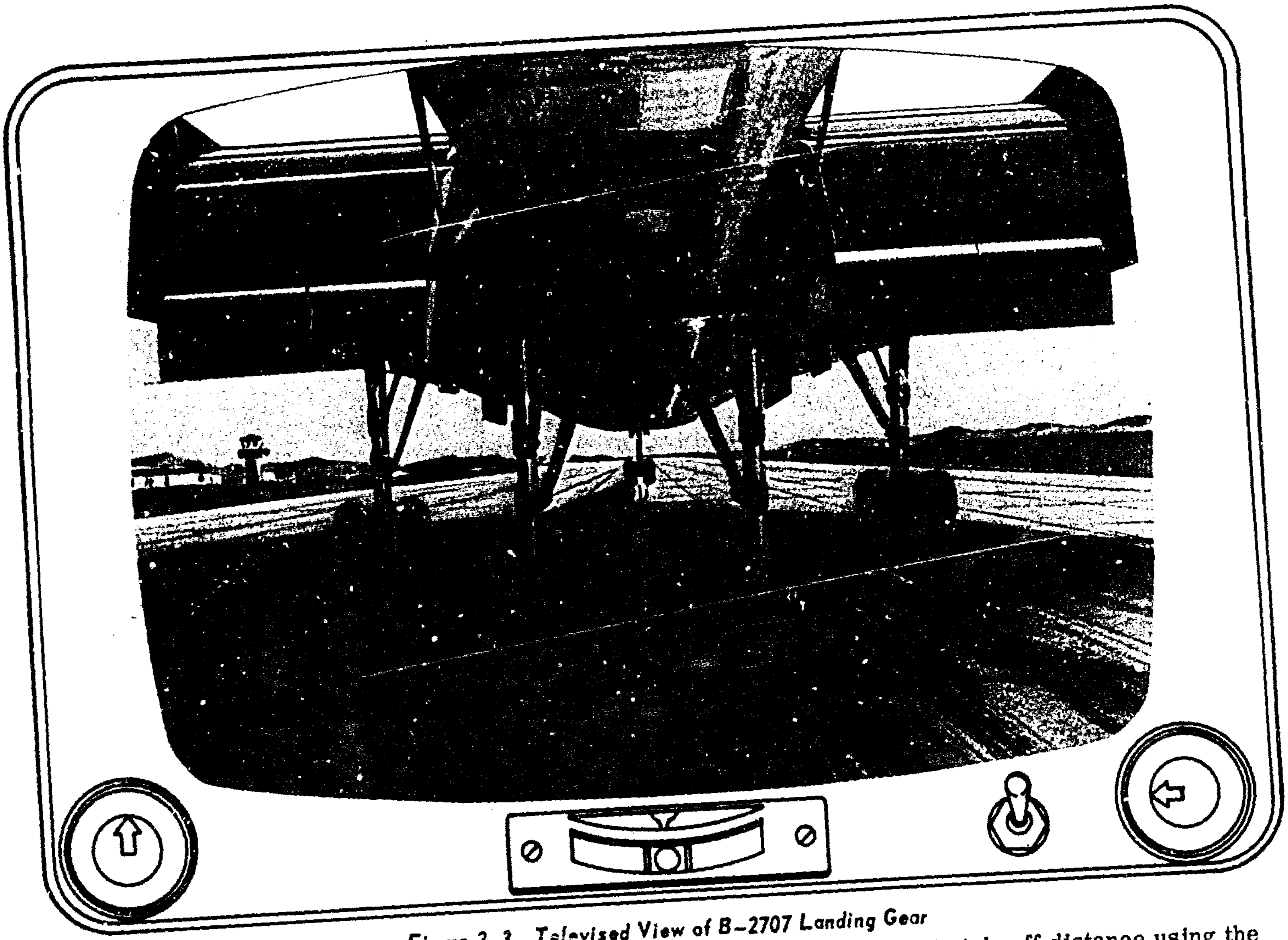


Figure 2-3. Televised View of B-2707 Landing Gear

tions. The engine acceleration characteristics are good with approximately 4 seconds (GE) from idle to 95 percent maximum dry thrust. The low idle thrust setting for ground operation at sea level is 1,530 lb per engine.

2.4 TAKEOFF

The takeoff performance of the B-2707 is considerably superior to that of current subsonic jet transports. The improved performance is due to the thrust requirement for transonic acceleration rather than takeoff. The rotation rates, liftoff speeds, and pitch attitudes are similar to those of current jet transports. The maximum inflight gross weight (flaps up), is 666,000 lb.

2.4.1 Normal Takeoff Procedures and Techniques

The takeoff procedures outlined in the following sections are similar to current practice. The takeoff thrust may be set prior to brake release or during the early part of the takeoff roll. There will be no increase in takeoff distance using the rolling takeoff procedure.

2.4.1.1 No Community or Airport Noise Restriction

Typical maximum gross weight takeoff and initial climb profiles are shown in Figs. 2-4 and 2-5. These profiles are based on the use of maximum augmented thrust.

The flap setting for the maximum gross weight takeoff is 20/40 deg (20 deg on main flap and 40 deg on auxiliary outer wing flap aft of main flap). The airplane is rotated at a rotation speed (V_R) schedule which provides a liftoff at an attitude of 10 deg with an average pull force of 15 lb. Rotation is initiated at a calibrated speed of 148 knots (1.12 V_{mcg}) with liftoff occurring at 169 knots for the maximum gross weight takeoff at maximum augmented thrust. Ground roll distance to liftoff is 4,800 ft. The FAR takeoff distance is 7,000 ft. Ample rudder control is

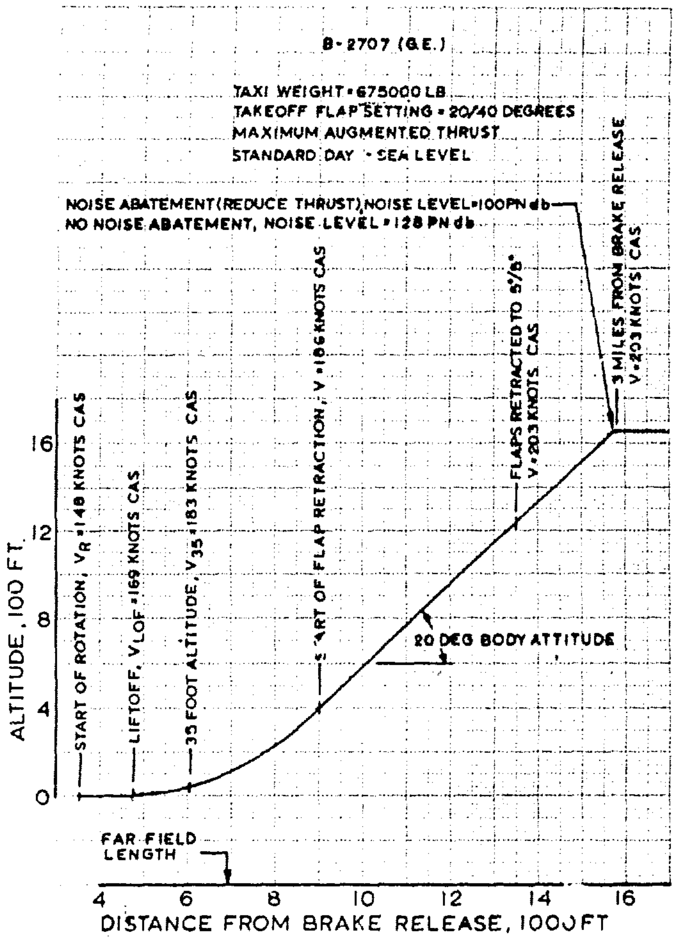


Figure 2-4. B-2707 (GE) Takeoff Profile

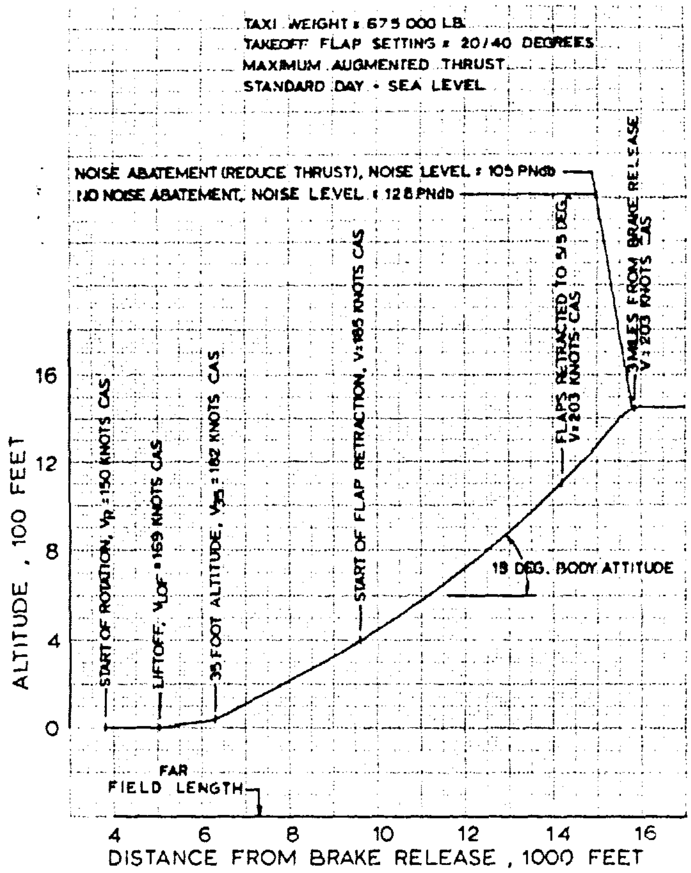


Figure 2-5. B-2707 (P&WA) Takeoff Profile

available for crosswind takeoffs. For the conditions of maximum augmented thrust, 675,000 lb gross weight and normal rotation speeds, the airplane can be held at zero yaw in a crosswind of 24 knots. For one engine inoperative, a zero yaw condition can be held in a 10-knot crosswind.

Gear retraction is initiated after a positive rate of climb is attained. The takeoff flare is completed at 186 knots and 250-ft altitude in a steady-state climb of 2,800 fpm. At the end of the takeoff segment, the wing flaps will be retracted and the wings will be swept to 42 deg. A summary of takeoff performance parameters for two gross weights are tabulated in Tables 2-A and 2-B.

2.4.1.2 Community Noise Abatement Restriction
At those airports where there are community noise abatement policies in effect, the typical takeoff procedure modifies the initial climb by making a smooth power reduction three miles from brake release. The thrust is reduced at the three mile point to 18,500 lb per engine. This results in a community noise level of 100 PNdb; the present FAA limit is 105 PNdb. The flight profile and the associated noise contours are shown in Fig. 2-6 through 2-9. The rapid climb rate achieved after liftoff results in low noise levels beyond the three mile point, using noise abatement procedures.

A summary of the community noise levels versus FAR field length and thrust setting is shown in Figs. 2-10 and 2-11.

2.4.2 Takeoff Field Lengths
The FAR takeoff field lengths for the B-2707 are considerably shorter than those of current commercial jet transports (Fig. 2-12). At a taxi gross weight of 675,000 lb, the standard day takeoff field length is 7,000 ft using maximum augmented thrust; at 86° F, the FAR takeoff field length is 8,300 ft.

Table 2-A. Takeoff Performance Summary – B-2707 (GE)

FIELD CONDITIONS	AIRPLANE CONDITIONS
Standard day	Wing sweep = 30 Degrees
Sea level	Flaps = 20/40 Degrees
Dry runway	Four engines operating
Zero wind, zero runway slope	

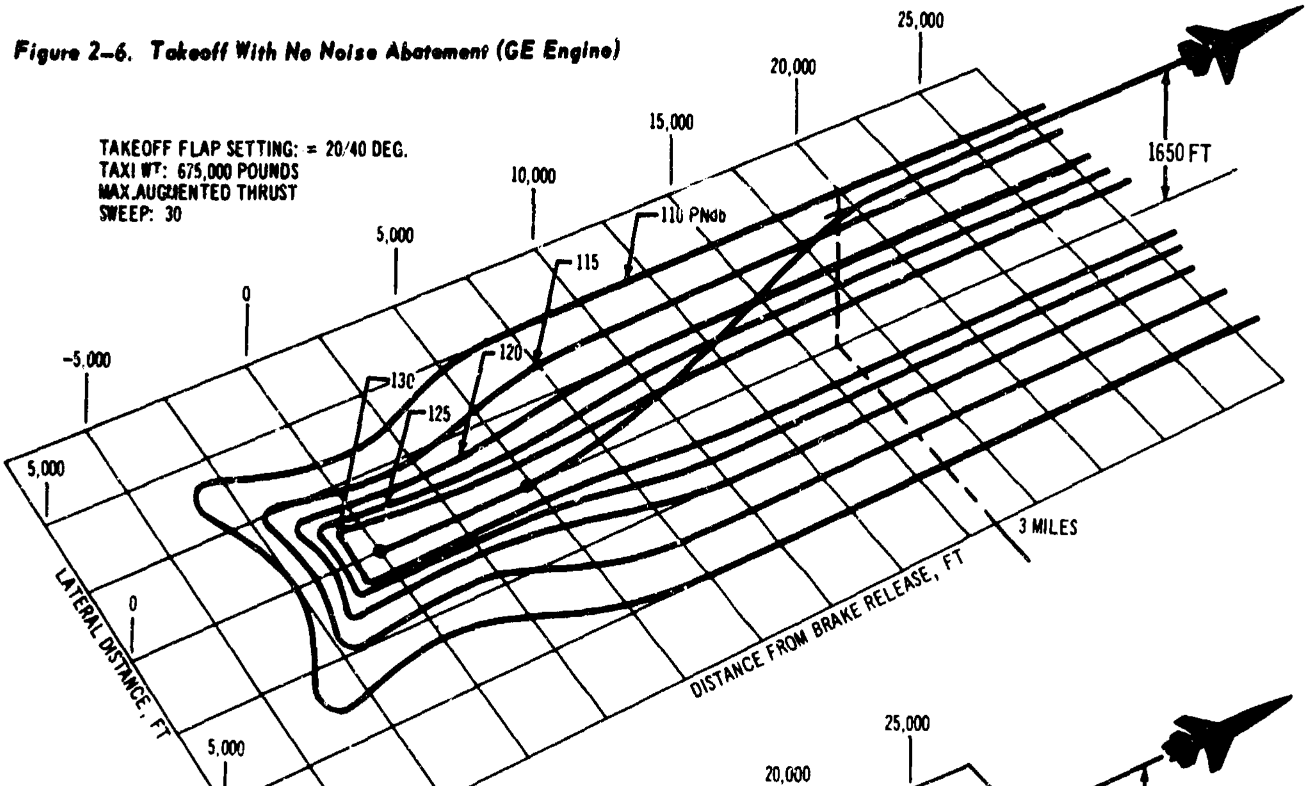
		Maximum Gross Weight	Alternate Gross Weight
Taxi gross weight (lb)		675,000	575,000
Thrust setting for takeoff		Max augmented	Max dry
T/W at liftoff		0.342	0.311
Airport noise (1,500 ft perpendicular to airplane path) (PNdb)		121	117
Takeoff criteria speeds (knots, CAS)	V_1	141	132
	V_R	148	139
	V_{LOF}	169	156
	V_{35}	183	167
Distances: (ft)	Brake release to 35 ft	6,050	5,800
	FAR field length	7,000	6,700
	Accelerate-stop (no reverse thrust)	6,450	6,200
Steady-state climb conditions			
After takeoff flare.			
Airspeed (kn, CAS)		186	169
Rate of climb (fpm)		2,800	2,400
Flight path angle (degrees)		8.5	8
Body angle (degrees)		20	19.5
Thrust reduced at 3 miles from brake release to observe community noise level requirement:			
Thrust reduced to		32.4% max augmented	35.5% max dry
Noise level (PNdb)		100	99
Airspeed (kn, CAS)		203	187
Altitude (ft)		1,650	1,430

Table 2-B. Takeoff Performance Summary – B-2707 (P&WA)

FIELD CONDITIONS	AIRPLANE CONDITIONS
Standard day Sea level Dry runway Zero wind, zero runway slope	Wing Sweep = 30 Degrees Flaps = 20/40 Degrees Four engines operating

	Maximum Gross Weight	Alternate Gross Weight
Taxi gross weight (lb)	675,000	575,000
Thrust setting for takeoff	Max augmented	0.5 Max augmented
T/W at liftoff	0.328	0.192
Airport noise (1,500 ft perpendicular to airplane path) (PNdb)	117	114
Takeoff Criteria Speeds: V_1	143	129
V_R	150	138
V_{LOF}	169	156
(kn, CAS) V_{35}	182	167
Distances: (ft) Brake release to 35 ft	6,325	6,450
FAR field length	7,300	7,400
Accelerate-stop (no reverse thrust)	6,800	6,900
Steady State Climb Conditions After Takeoff Flare:		
Airspeed (kn, CAS)	185	168
Rate of climb (fpm)	2,600	2,200
Flight path angle (degrees)	8	7.5
Body angle (degrees)	19.5	19
Thrust reduced at 3 miles from brake release to observe community noise level requirement:		
Thrust reduced to	33.9% max augmented	28.8% max augmented
Noise level (PNdb)	105	103
Airspeed (kn, CAS)	203	187
Altitude (ft)	1,450	1,290

Figure 2-6. Takeoff With No Noise Abatement (GE Engine)



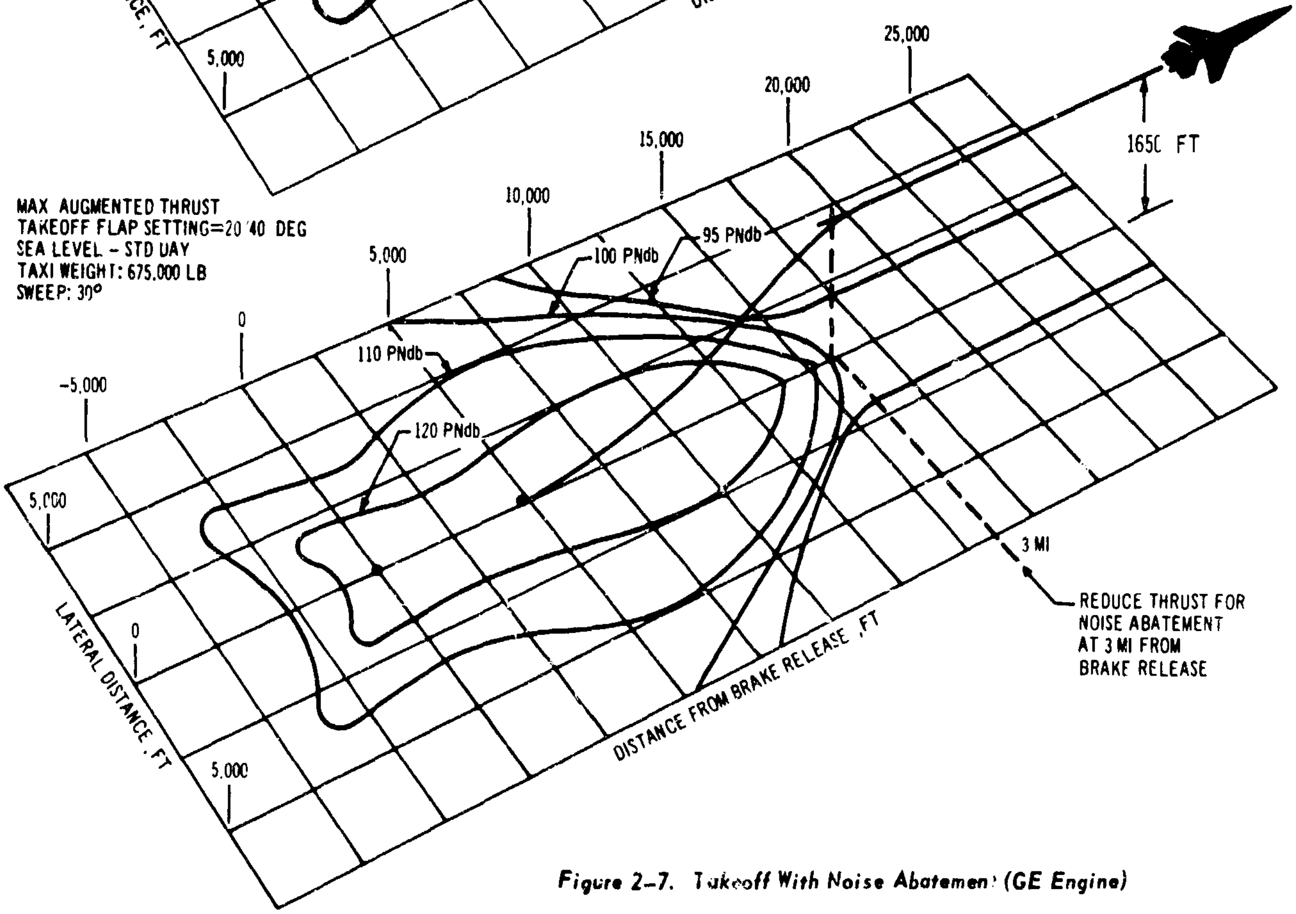
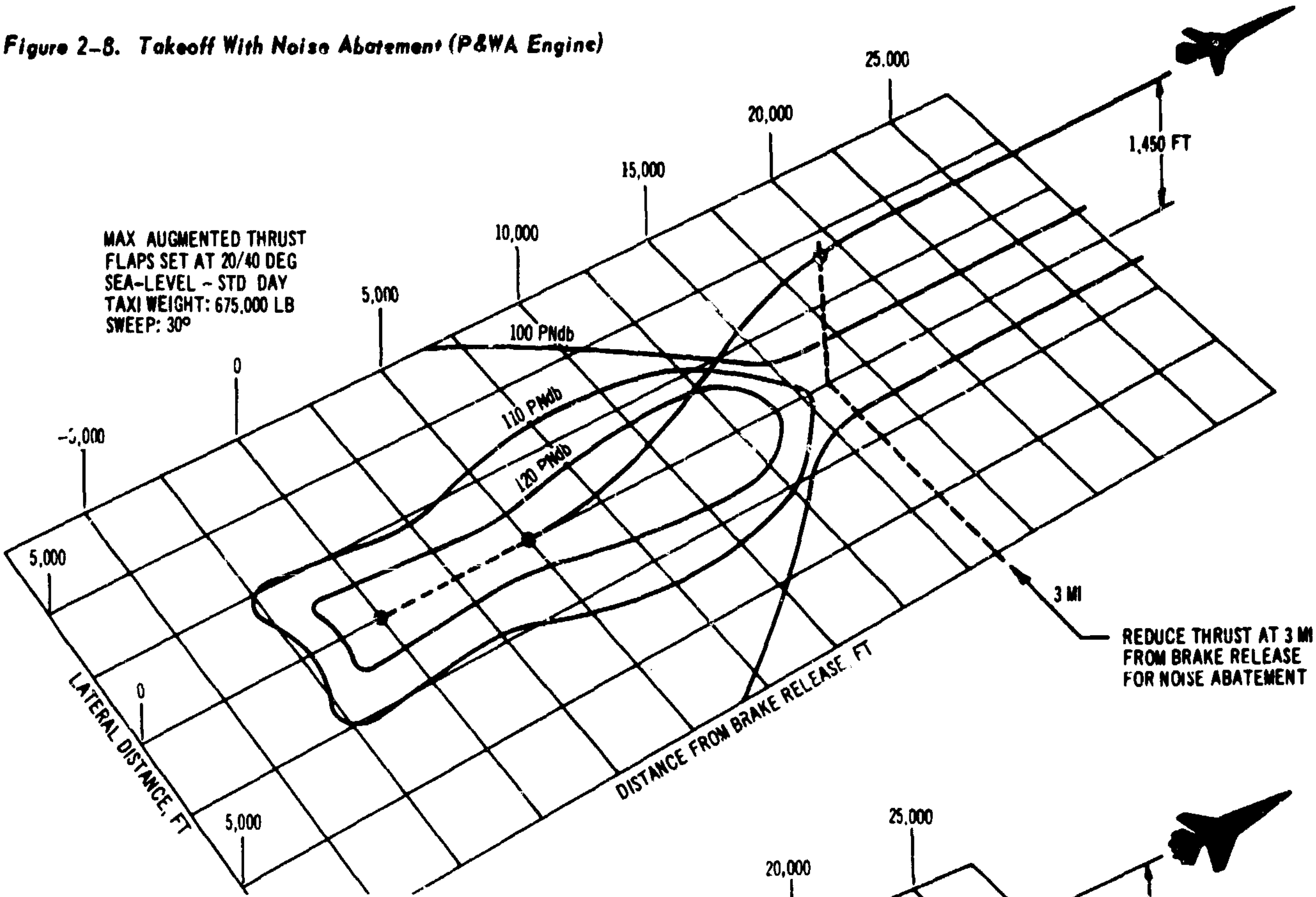


Figure 2-7. Takeoff With Noise Abatement (GE Engine)

Figure 2-8. Takeoff With Noise Abatement (P&WA Engine)



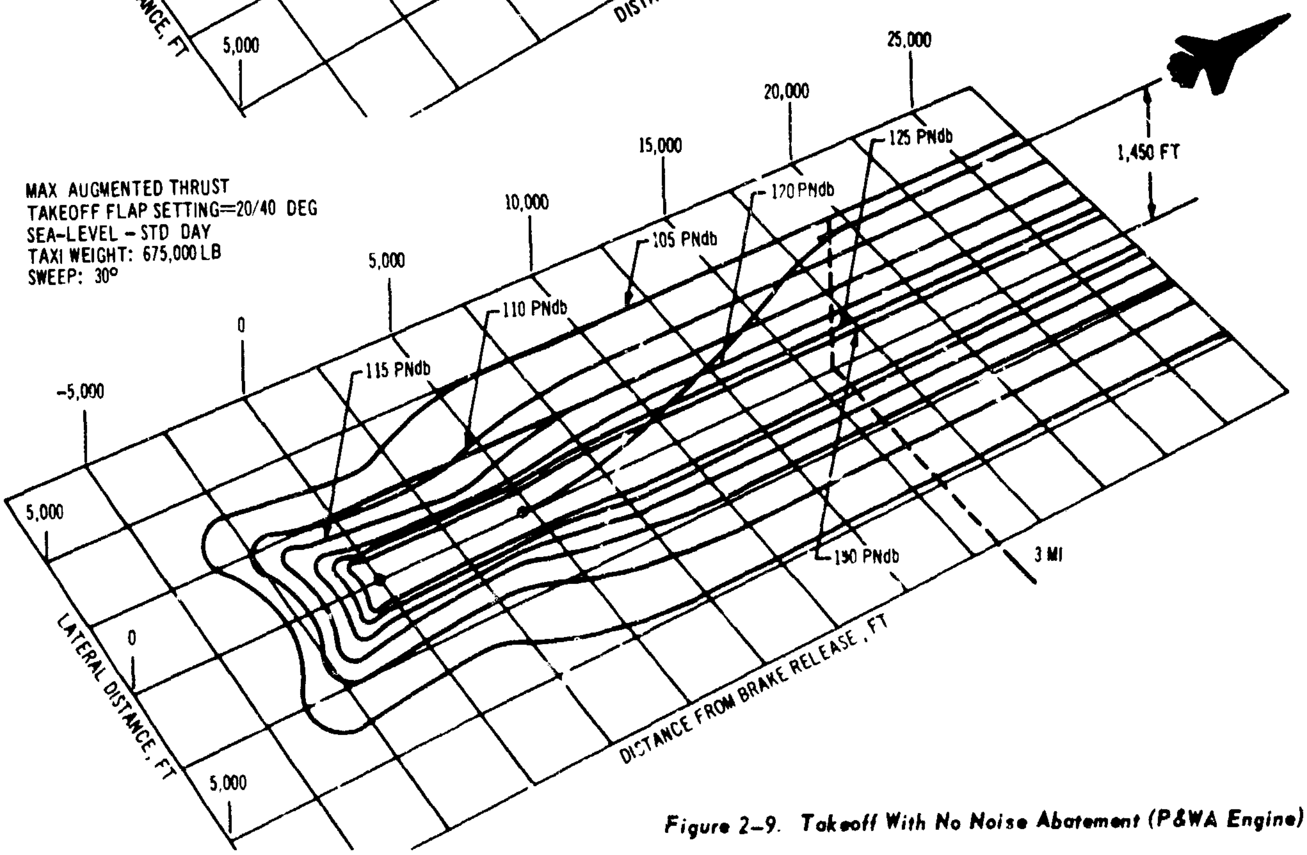


Figure 2-9. Takeoff With No Noise Abatement (P&WA Engine)

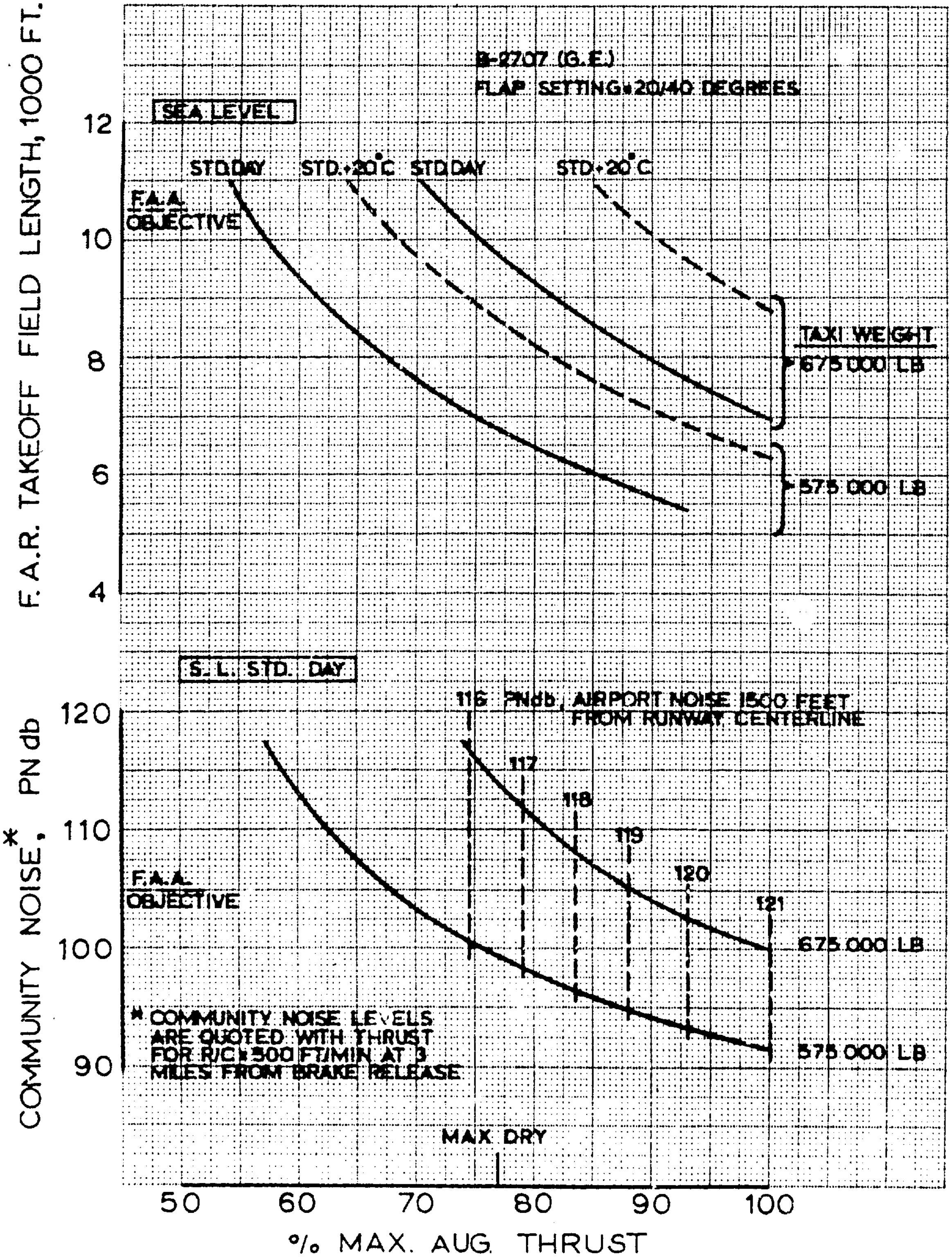


Figure 2-10. B-2707 (GE) Takeoff Noise Trades

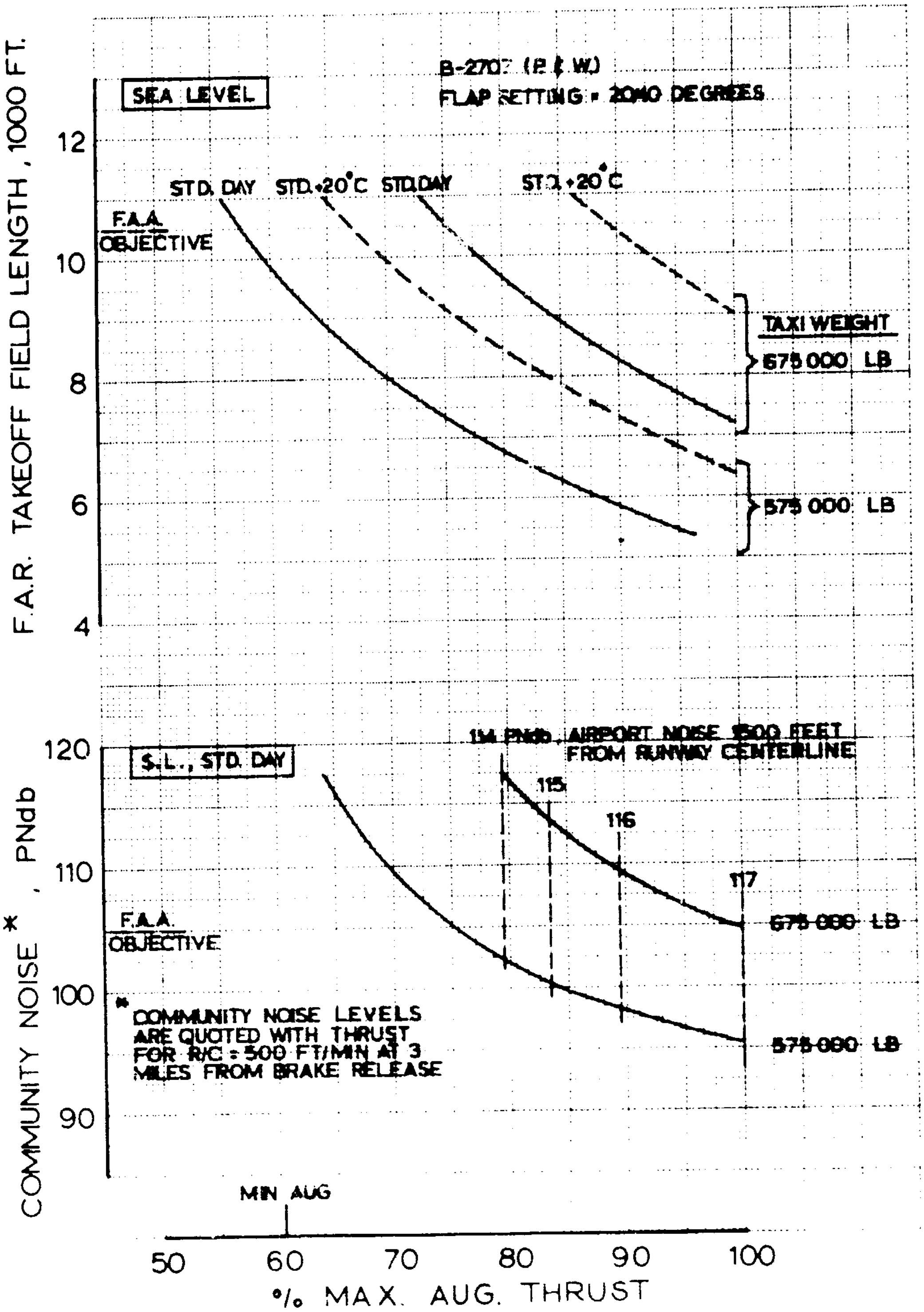


Figure 2-11. B-2707 (P&WA) Takeoff Noise Trades

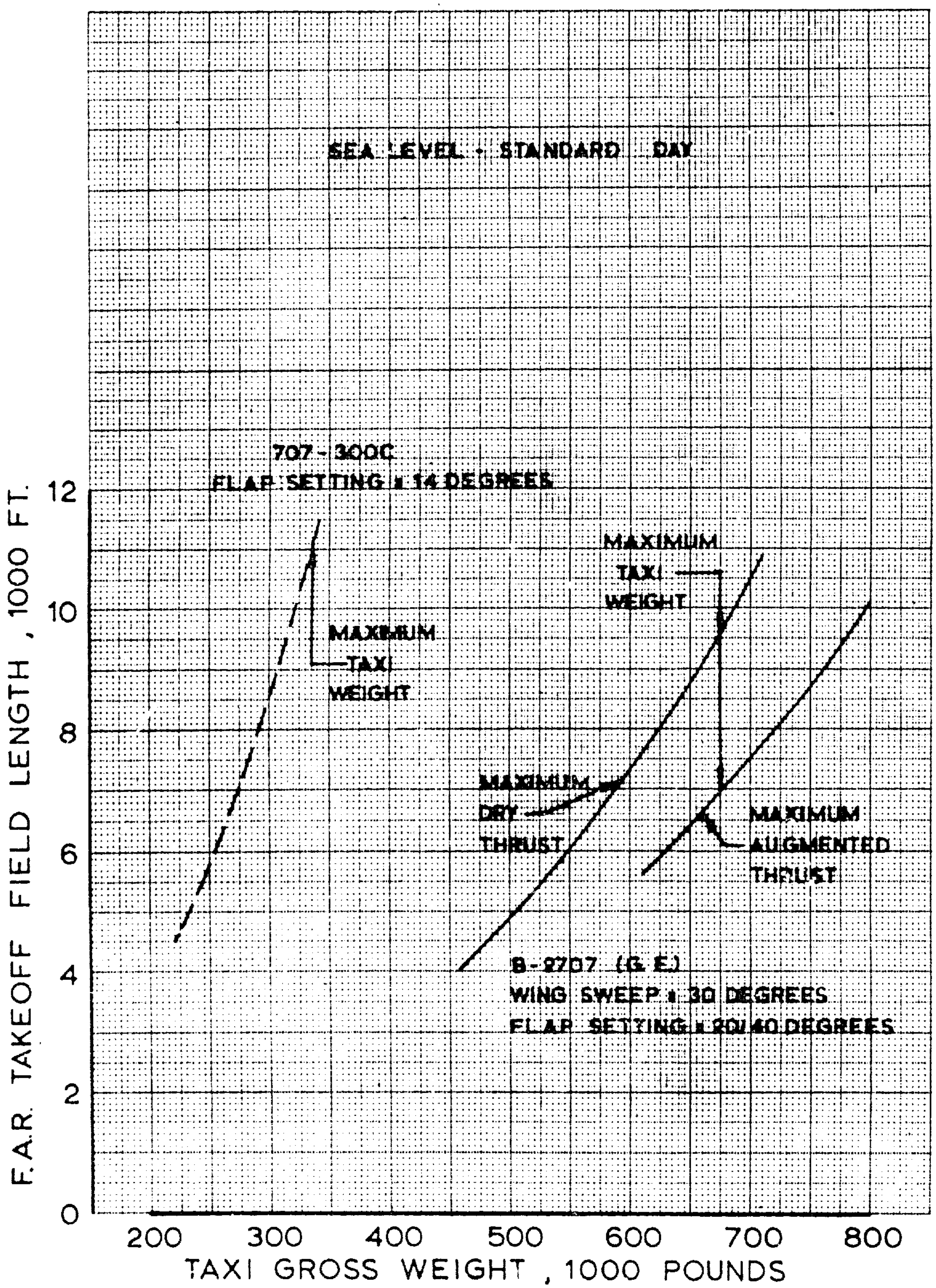


Figure 2-12. Takeoff Field Length Comparison

The takeoff speeds shown in Figs. 2-13 and 2-14 were developed on the basis of a 10-deg angle of attack at liftoff, which provides a 2-ft tail clearance with oleos extended.

The liftoff speeds are estimated to be considerably in excess of 10 percent over the non-geometry limited minimum unstick speeds (current FAR). This provides climb capability after liftoff substantially greater than subsonic jets. The geometry of the airplane prevents demonstration of minimum unstick speed in ground effect; however, the liftoff speeds are always at least 5 percent above the geometry-limited minimum speed.

2.4.3 Engine Failure During Takeoff
The engine failure speeds (V_1), using maximum augmented or maximum dry thrust for the normal takeoff gross weight range of the airplane, are shown in Figs. 2-13 and 2-14. The stopping distance is determined on the basis of using only aerodynamic drag and wheel brakes. The spoiler segments on the upper wing surface, when used as speed brakes, increase aerodynamic drag and wheel brake effectiveness. In actual operation, however, reverse thrust may be used as an additional braking force. Actuation of the reverse thrust mechanisms on the B-2707 is similar to that of the 707. Reverse thrust is obtained by actuating the "piggyback" levers on the thrust levers (Fig. 2-15).

If an engine failure occurs after the V_1 speed has been reached, the takeoff is continued. The high thrust-to-weight ratio during takeoff provides an additional safety margin in the form of excellent climb performance with one engine inoperative (Par. 2.4.4). Sufficient rudder control is available to permit maximum use of maximum augmented thrust while maintaining zero yaw in a 10-knot crosswind at normal rotation speeds.

Table 2-C shows the minimum control speeds on the ground and in the air. The nosewheel steering on the rudder pedals is ±5 deg so that effectiveness under wet or icy runway conditions can be maintained. The ground minimum control speed (V_{mcg}) for three engines at maximum augmented thrust is 132 knots, taking no credit for nose wheel steering effectiveness. A wet runway nose wheel effectiveness calculation shows that V_{mcg} is 118 knots. The critical engine failure speed (V_1) for a maximum gross weight of 675,000 lb is 141 knots CAS.

Figure 2-16 shows the balanced field length breakdown for a standard day, maximum gross weight, maximum augmented thrust condition. A summary of stopping capability for various stopping or decelerating configurations is shown in Fig. 2-17.

2.4.4 Performance Margins
A high thrust-to-weight ratio during takeoff results in safety margins far in excess of those on current jet transports. A thrust-to-weight ratio of 0.34 is obtainable at maximum augmented thrust on the B-2707 for the maximum gross weight configuration, compared to 0.18 for the similar takeoff configuration of a Boeing 707-320 series airplane. The airplane is accelerating at 4.1 knots per second at liftoff during a maximum gross weight takeoff. From the stall speeds determined during certification, a stick shaker warning system will be set for the required margin above the thrust-off stall speeds. The speed margin between initial buffet and estimated 1g thrust-off stall speed in the takeoff configuration is approximately 5 knots. The speed margin between the normal liftoff speed and the speed for heavy buffet or zero rate of climb, thrust on, is at least 40 knots.

The thrust-off stall speeds are considerably higher than the zero rate-of-climb speeds with maximum augmented thrust. Since the airplane is geometry limited by the ventral fin on takeoff, it is impossible for early or over-rotation to significantly affect takeoff distance (Fig. 2-18). The V_2 speeds shown in Fig. 2-19 are approximately 10 knots above liftoff speed as the airplane passes through 35 ft above the ground. The airplane will stabilize at a speed greater than V_2 at a height of approximately 250 ft, depending on the rotation rate. V_2 + 10 knots is an estimated 4-engine climb speed based on experience in the 707 and 727 at comparable thrust-to-weight ratios.

The possibility of slush, water, and foreign objects being thrown into the engine inlet from the wheels during takeoff will not be a problem due to the shielding effect of the main flaps forward of the engine inlets (Par. 2.14).

2.4.5 Handling Characteristics
The classical dynamic stability requirements deal generally with the airplane's hands off response, or open-loop stability. However, of equal importance to the open-loop stability is the behavior of the closed-loop system, consisting of the instru-

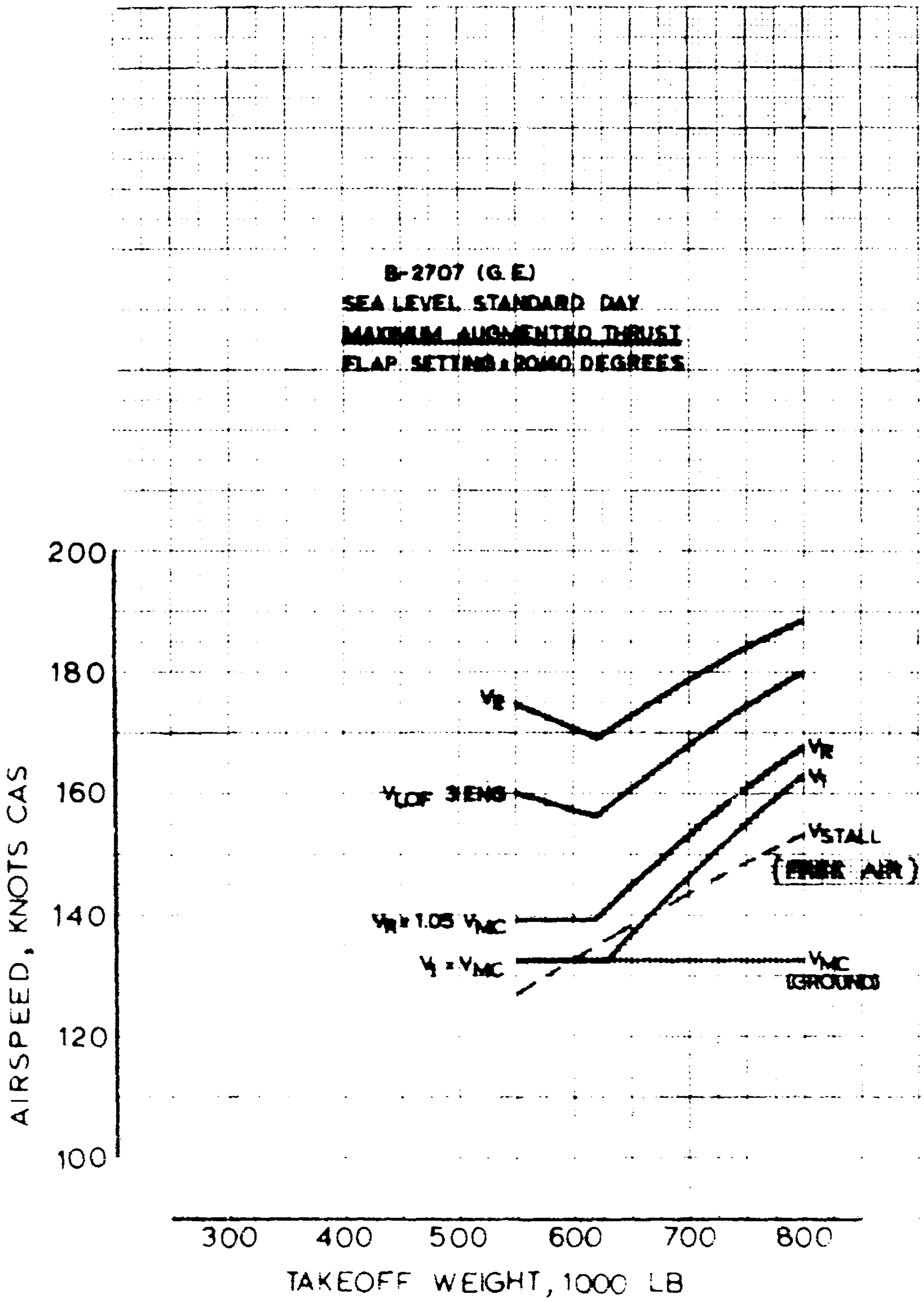


Figure 2-13. Takeoff Speeds (Maximum Augmented Thrust)

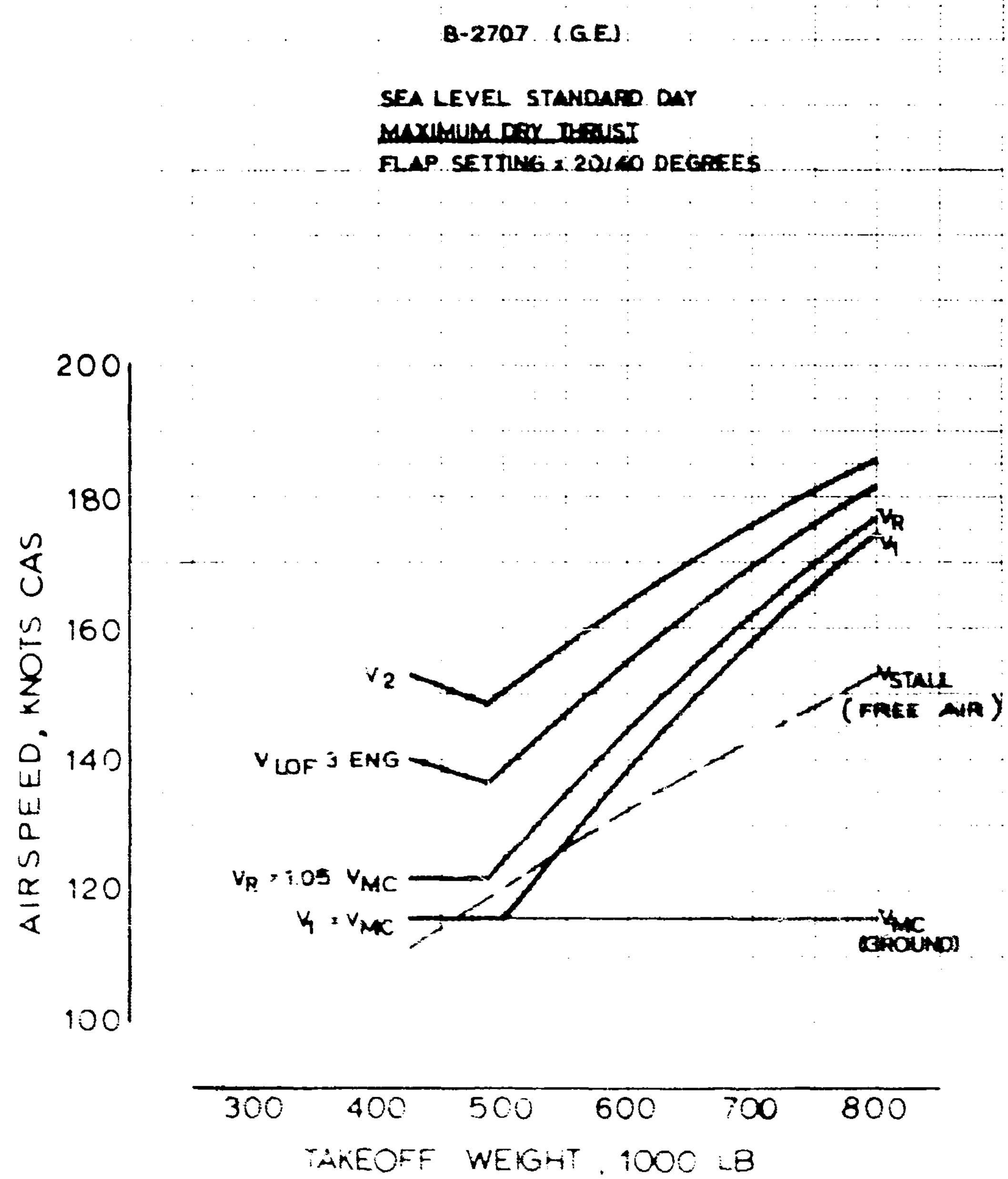


Figure 2-14. Takeoff Speeds (Maximum Dry Thrust)

Table 2-C. B-2707 (GE) Minimum Control Speeds

B-2707 (GE)

Minimum Control Speeds - V_{MC}

Sea Level Standard Day

Ground Conditions	V_{MC} - Knots CAS
One outboard engine inoperative Three engines at maximum augmented thrust No nose wheel steering	132
One outboard engine inoperative Three engines at maximum augmented thrust With nose wheel steering (wet runway $\mu = 0.16$)	118
One outboard engine inoperative Three engines at maximum dry thrust No nose wheel steering	117
One outboard engine inoperative Three engines at maximum dry thrust in reverse No nose wheel steering	68
Airborne Conditions	
One outboard engine inoperative Three engines at maximum augmented thrust Estimated two degree bank angle	118
One outboard engine inoperative Three engines at maximum dry thrust Estimated two degree bank angle	101
Two engines inoperative on same side Two remaining engines at maximum dry thrust Estimated two degree bank angle	135

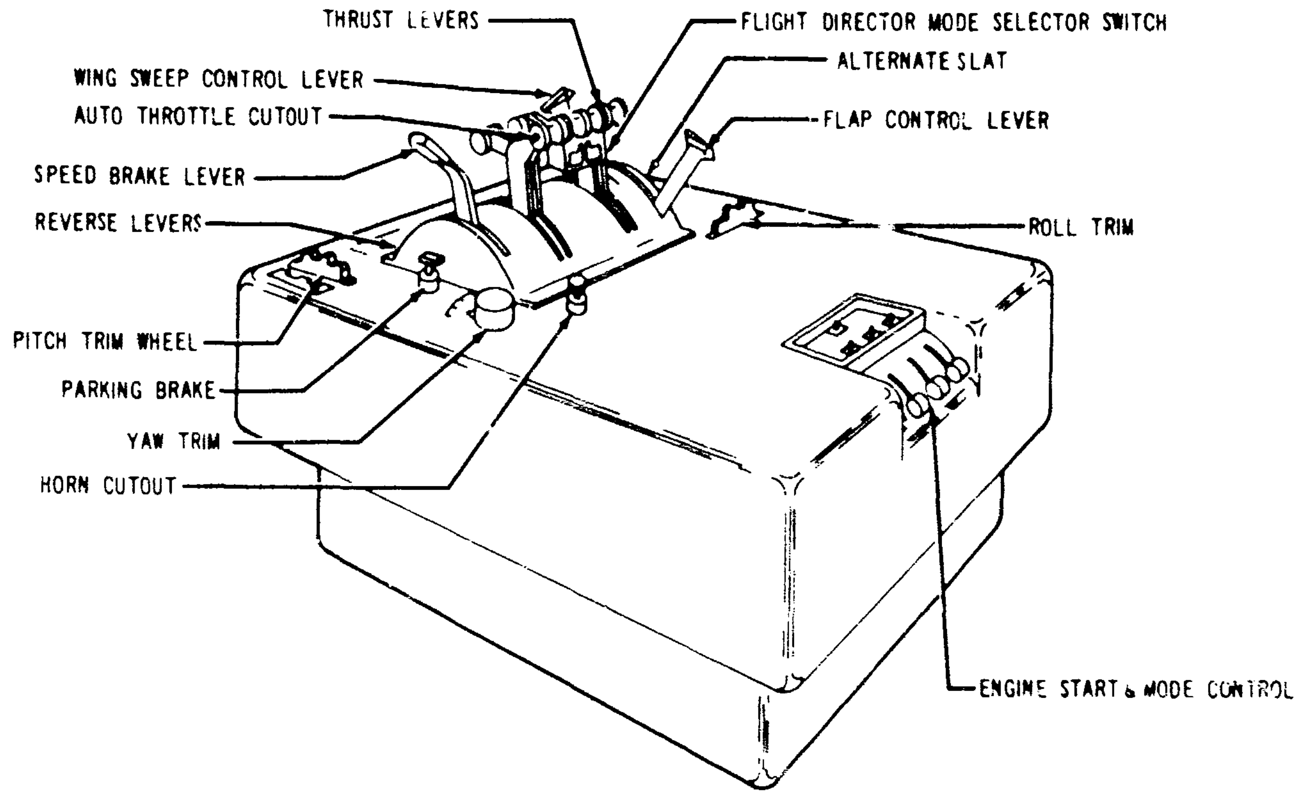


Figure 2-15. Center Aisle Control Stand

mentation, the pilot, the control system, and the airplane. Therefore, it is important that the stability augmentation devices augment the closed-loop system as well as the airplane-free dynamic stability characteristics. Consequently, airplane handling qualities as discussed in this document are defined as the airplane's response characteristics to the pilot's control inputs (as well as the hands off response to turbulence, trim changes, etc.).

2.4.5.1 Longitudinal Control
Simulator studies indicate that although the pitch response is slow, the airplane is manageable without augmentation and very good with augmentation. An ILS can be flown in rough air on instruments to present-day minimums with stability augmentation system (SAS) off using deviation data only. Consequently, a takeoff with SAS off is no problem. The flight director also improves the SAS off situation. An improved attitude indicator is under development which has increased pitch and roll attitude resolution. This indicator will increase considerably the controllability of the airplane with SAS off as well as on.

The body attitude of the airplane at liftoff is 10 deg (very similar to 707 and 727 liftoff attitudes).

In areas with noise restrictions, the attitude is increased to approximately 20 deg during initial climb.

The high angle of attack longitudinal characteristics and lateral control power at speeds lower than the stall speed are sufficiently effective for recovery from any stall condition. Simulator studies show that the addition of maximum dry thrust at low altitudes prevent any appreciable altitude loss when recovering from angles of attack in excess of 25-30 deg.

2.4.5.2 Lateral-Directional Control
The rudder pedal forces and general controllability with an outboard engine failure during takeoff are satisfactory. The airplane also has aileron and rudder controls which can easily handle crosswinds in excess of 24 knots, and crosswinds of 30 knots with one outboard engine out at the more critical lighter weight conditions (Table 2-C).

The maximum rudder pedal force is 80 lb at maximum pedal deflection. This level and the initial pedal force deflection of 50 lb for 25-percent pedal travel was determined from 727 experience.

The airplane is heavily damped in the dutch roll mode without stability augmentation and has very little adverse yaw during turn entry and exit. The spiral mode is practically neutral. The roll mode is also heavily damped. Handling with lateral directional augmentation off is very good.

2.4.6 Departure Air Maneuver

The Phase III supersonic economic ground rules for performance state that the time and fuel required for a 4-minute departure air maneuver must be included in all mission planning. This maneuver is calculated at 250 knots, 5,000 ft altitude, with the wing sweep angle set at 42 deg.

2.5 CLIMB AND ACCELERATION

2.5.1 General

The climb and acceleration from the end of takeoff to supersonic cruise altitude is planned to ensure acceptable noise levels and overpressures.

Flight techniques for climb and acceleration are conventional. However, the increased performance of this airplane materially reduces the time spent at the lower altitudes (Fig. 2-20). Therefore, simplified departure routing is essential to the efficient operation of the B-2707.

The procedure for this segment of the flight is to climb at a constant indicated airspeed to the transonic acceleration altitude. A climb is maintained along the sonic boom constant overpressure profile to final climb, then the final climb airspeed is maintained at the initial cruise altitude.

The transonic acceleration may be accomplished, depending on the departure routing, so that the ground overpressure will not exceed some arbitrary level such as 2.5 psf, or the airplane can climb along the V_{MO}/M_{MO} climb schedule if there are no sonic boom restrictions. Approximately 3.3 psf overpressure would be generated during transonic acceleration, along the V_{MO}/M_{MO} climb schedule, with an increase in range. The excess thrust increases as the airplane reaches speeds beyond Mach 1.4 (Fig. 2-21). The level flight thrust required and thrust available plots (Fig. 2-22) show the speed-thrust stability typical of supersonic aircraft. The sharp thrust drop-off beyond Mach 2.8, due to the engine inlet characteristics, significantly reduces the tendency of the airplane to overspeed. The auto-throttles will be very useful during cruise to maintain the desired Mach number and further reduce the possibility of overspeed. Auto-throttles may be engaged just prior to level-off at cruise so that Mach 2.7 will not be exceeded while the pilot is setting up cruise altitude. The pilot may also set the autopilot up to capture the cruise altitude automatically so that he only needs to monitor level-off.

The B-2707 has an adequate thrust margin in the climb, as indicated by the service ceiling margins shown in Figs. 2-23 and 2-24. This provides operational flexibility with respect to weather and possible atmospheric temperature variations. Normal climb schedules are shown in Figs. 2-23 and 2-24 The maximum $\Delta P = 2.5$ psf denotes the maximum overpressure obtained during the climb between Mach 1.15 and Mach 1.9. The effect of these climb schedules on total range is shown in Fig. 2-25.

2.5.2 Instrumentation

Instrument references are materially improved over present subsonic jet transports in manual control during the climb as well as cruise and descent. In addition, the CAS overpressure profile and rate-of-climb modes of the autopilot and flight director system are available to assist the pilot.

The rate-of-climb instrument can be considered as an indication of the excess thrust available to the airplane at a constant true airspeed. Reducing the rate of climb will make additional thrust available (at the same thrust setting), for acceleration, thus trading climb capability for acceleration. On this basis, the accurate and instantaneous rate of climb and airspeed information available from the air data systems are used to determine progress during the acceleration. The indicated Mach and true airspeed instruments are used to monitor the acceleration. Digital readouts are provided on these instruments to best display speed and rate of change of speed and rate of climb. Research is under way to determine the feasibility of an instrument that combines rate of climb and speed rate to display a parameter proportional to net excess thrust.

Additional pilot aids to fly the sonic boom ΔP segments are: (1) A pre-computed ΔP flight path pitch attitude command signal will be presented as a mode of the flight director; (2) a supporting situation display which is being considered, may be employed to receive information from the air

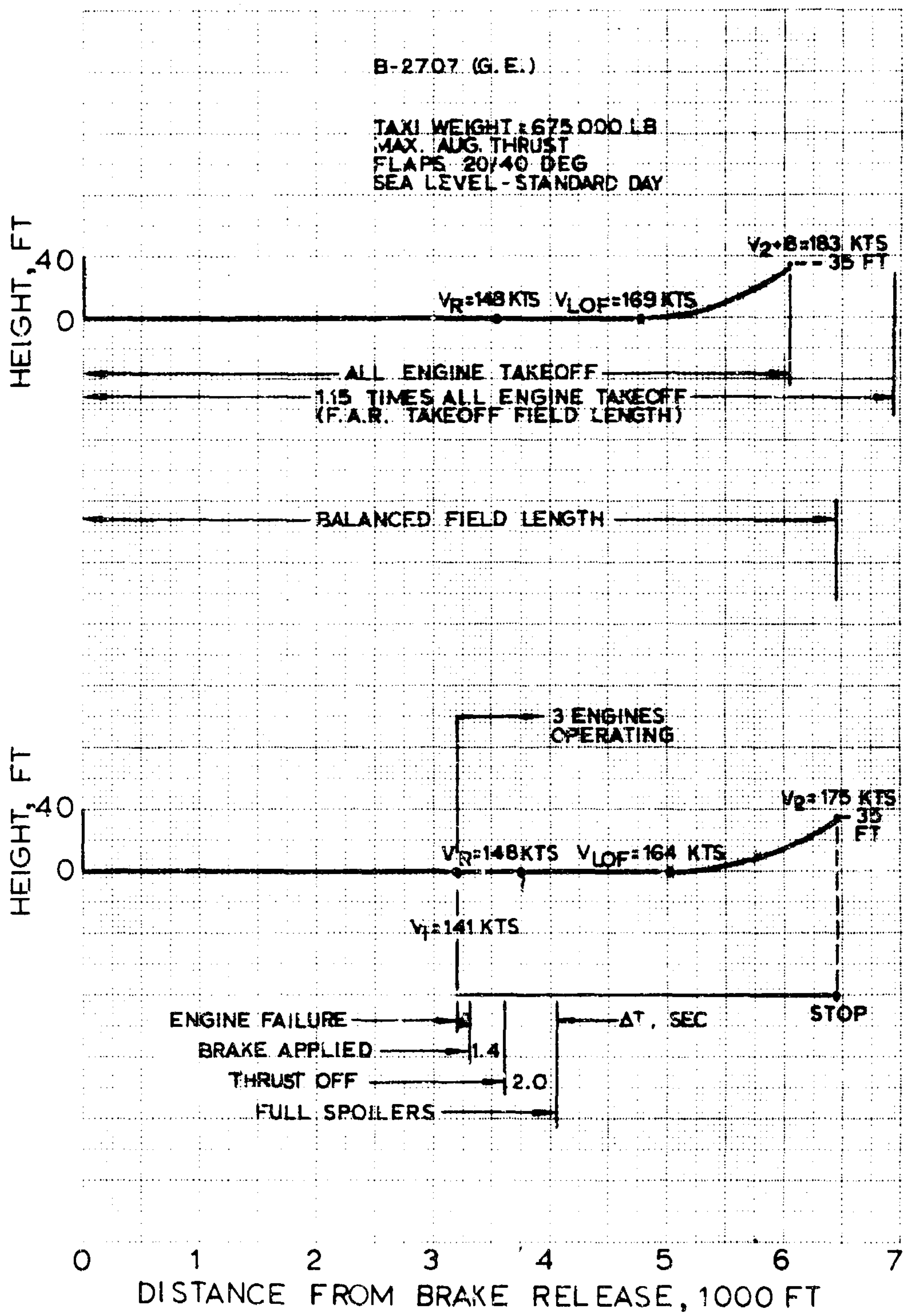


Figure 2–16. Balanced Field Length

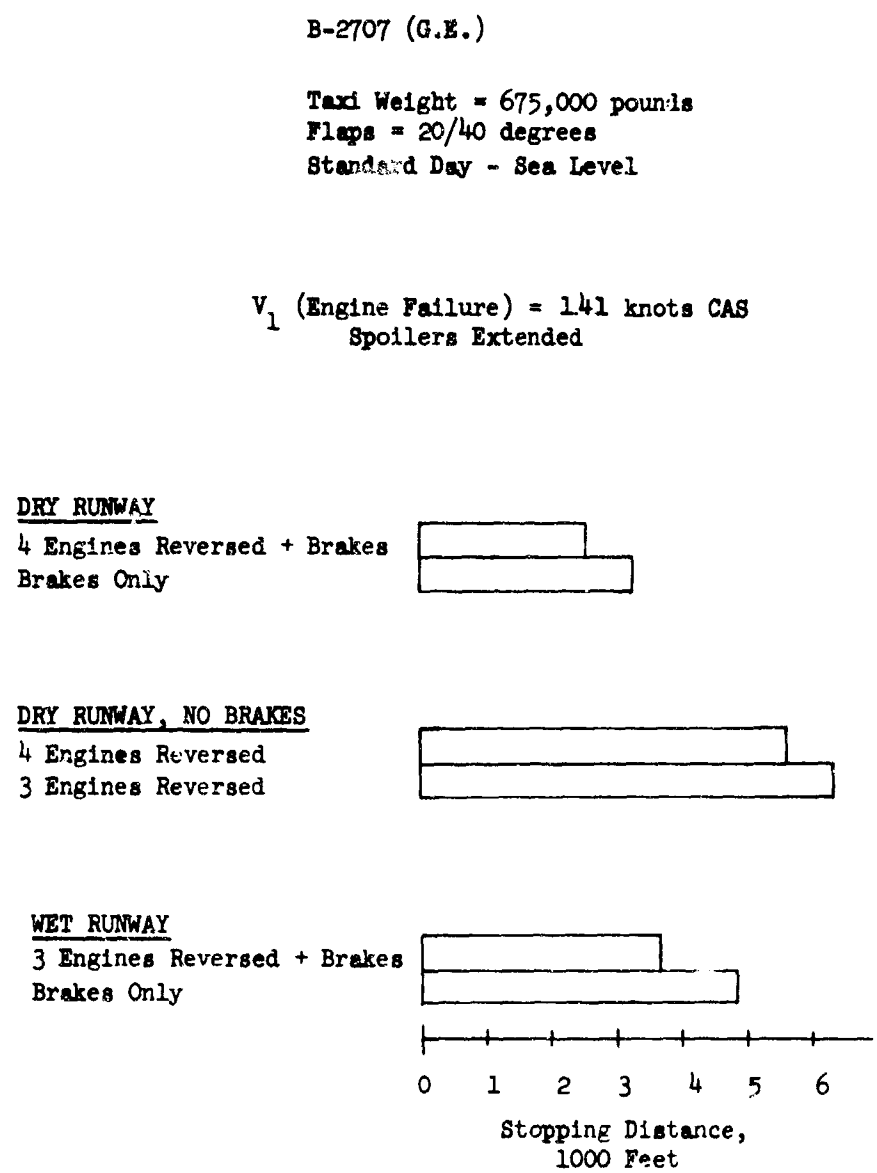


Figure 2-17. Stopping Capability

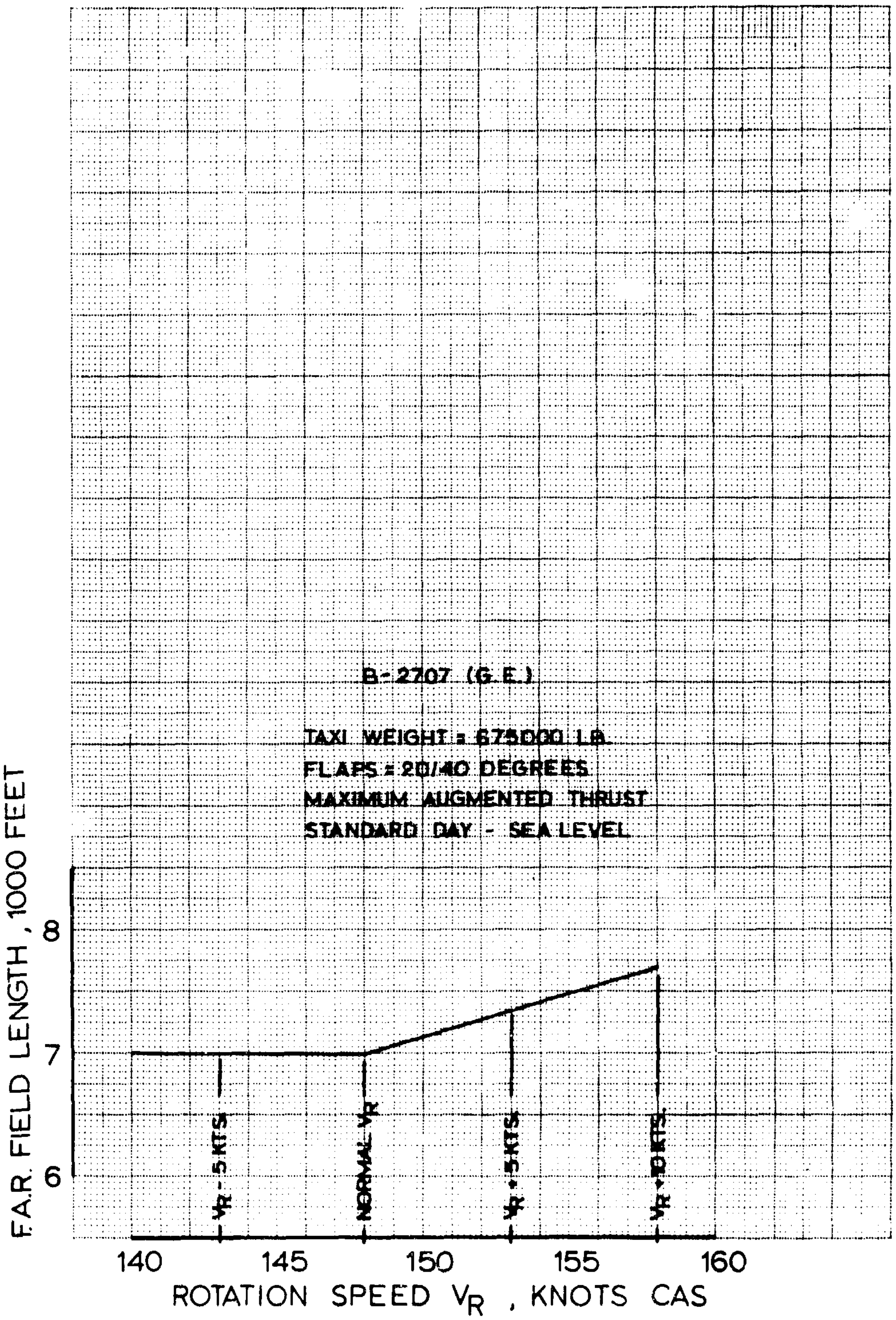


Figure 2-18. Effect of Rotation Speed on FAR Field Length

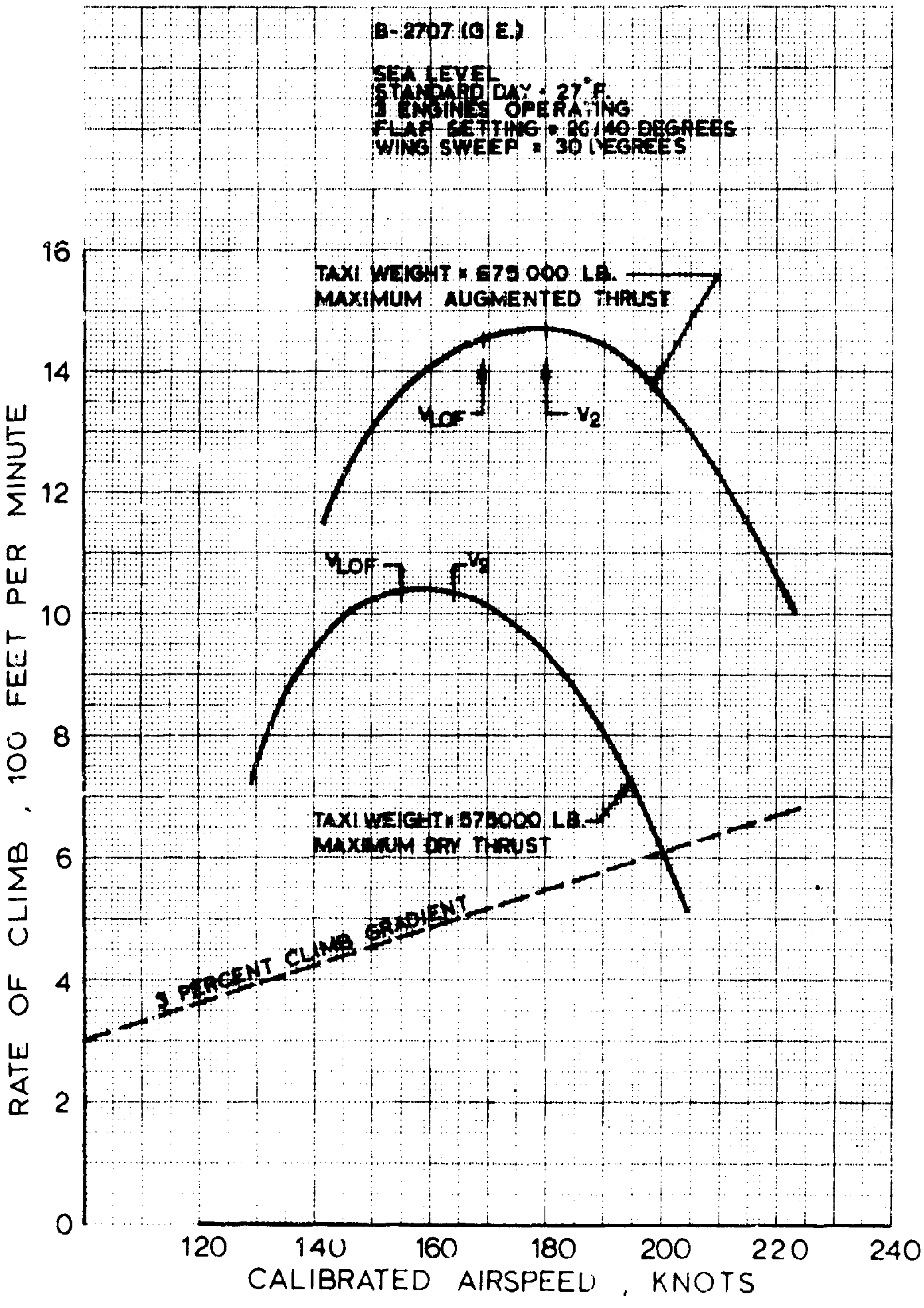


Figure 2-19. Takeoff Climb Capability

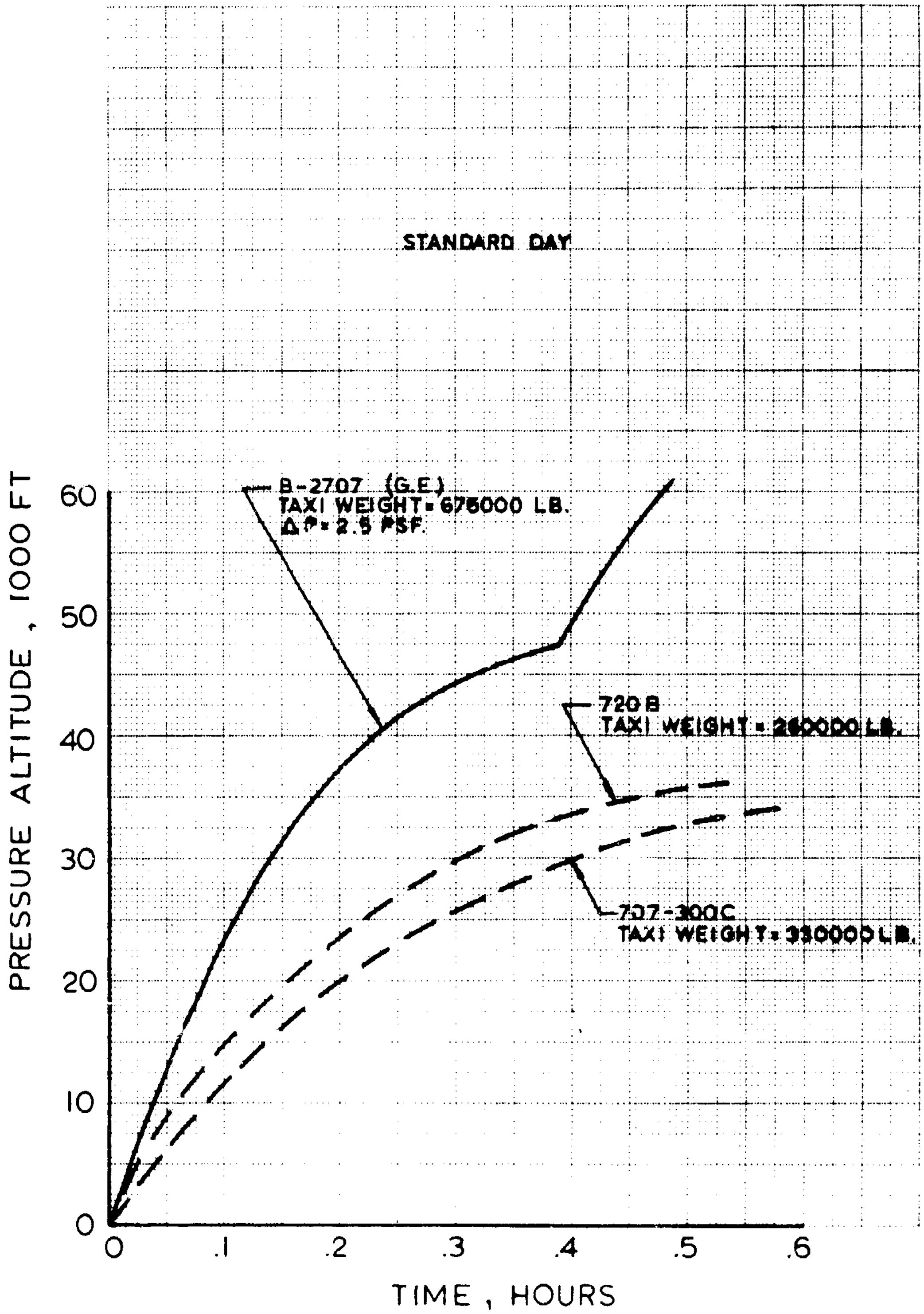


Figure 2-20. Climb Time

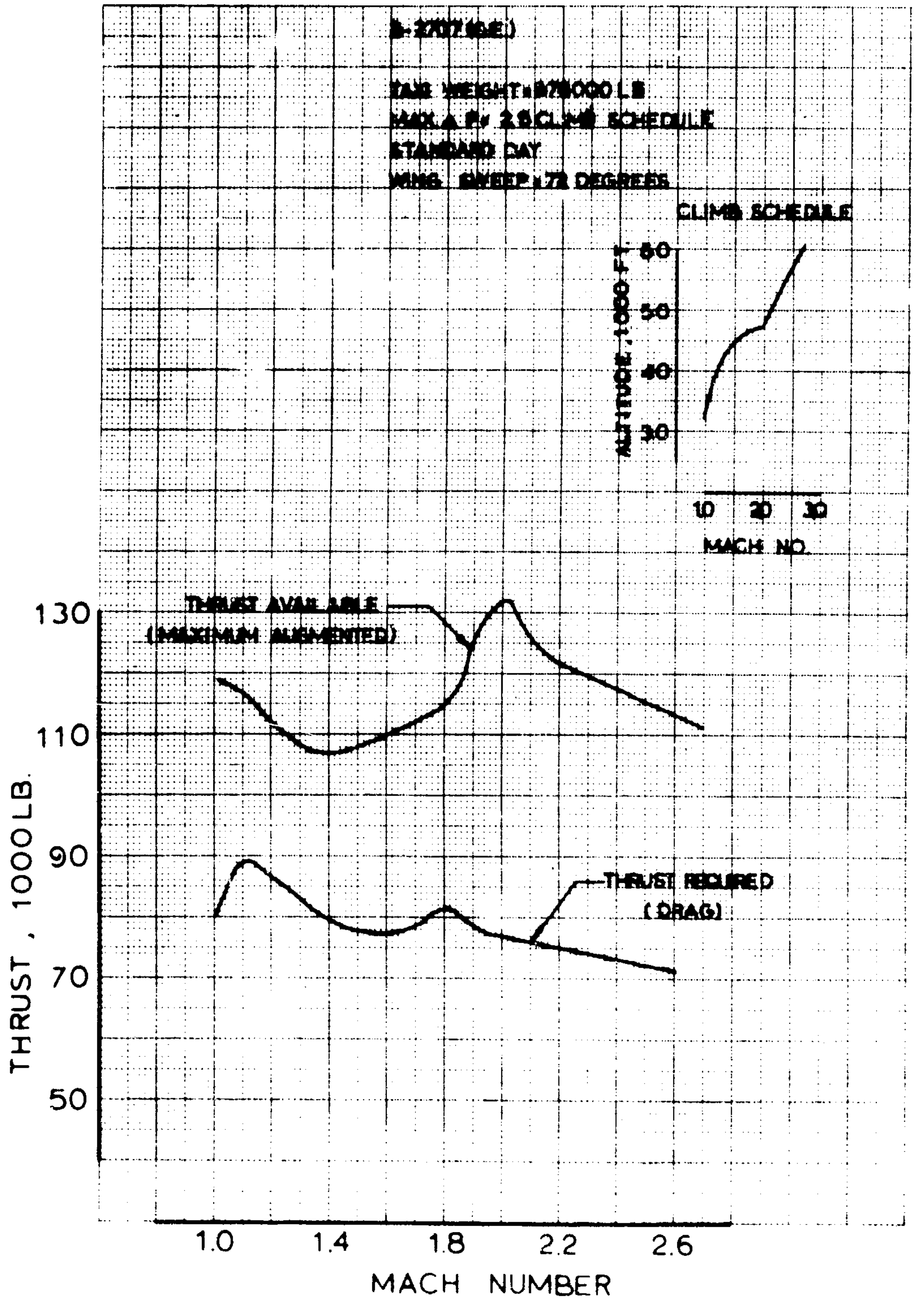


Figure 2-21. Thrust Margin During Supersonic Climb

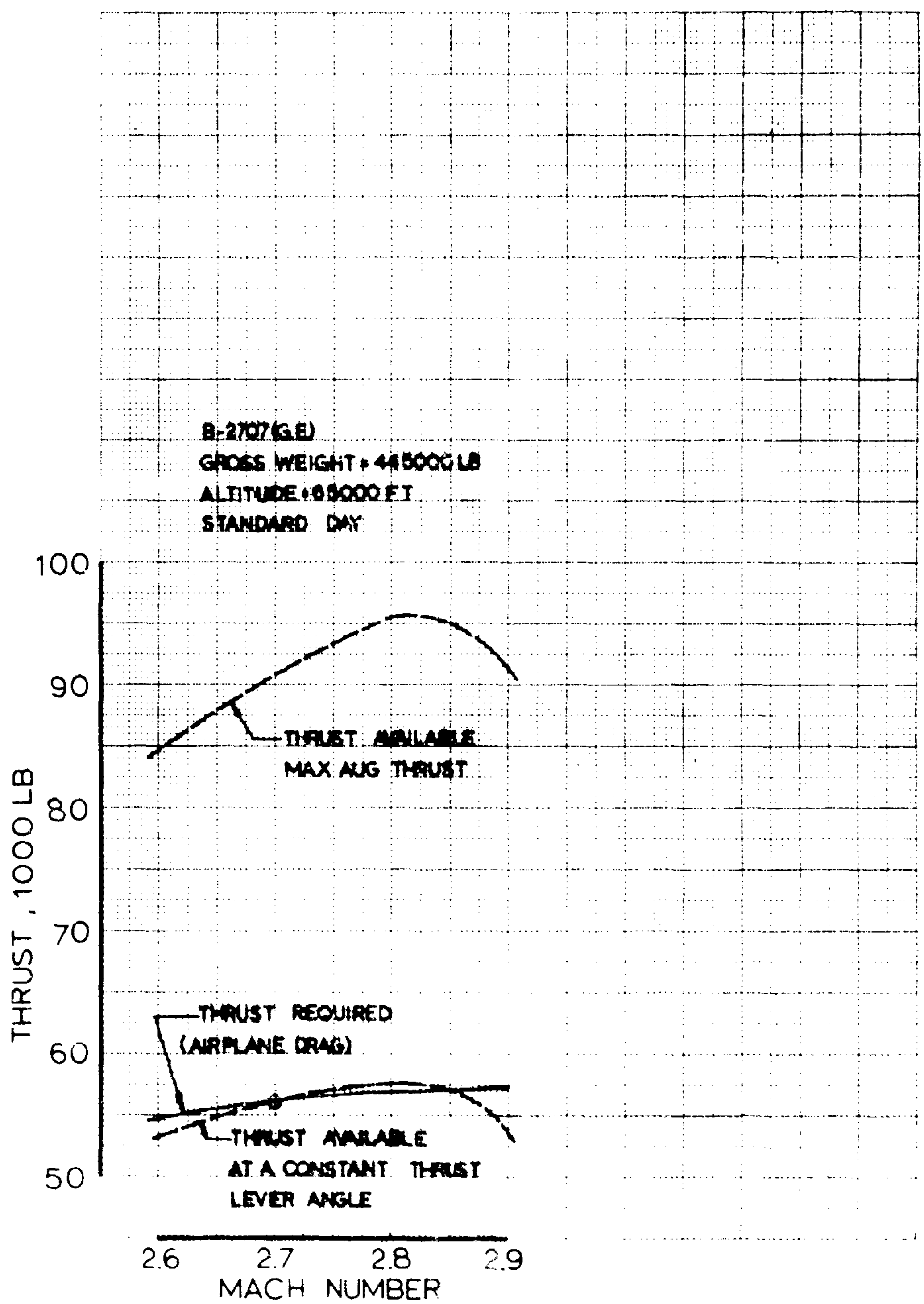


Figure 2-22. Thrust Stability

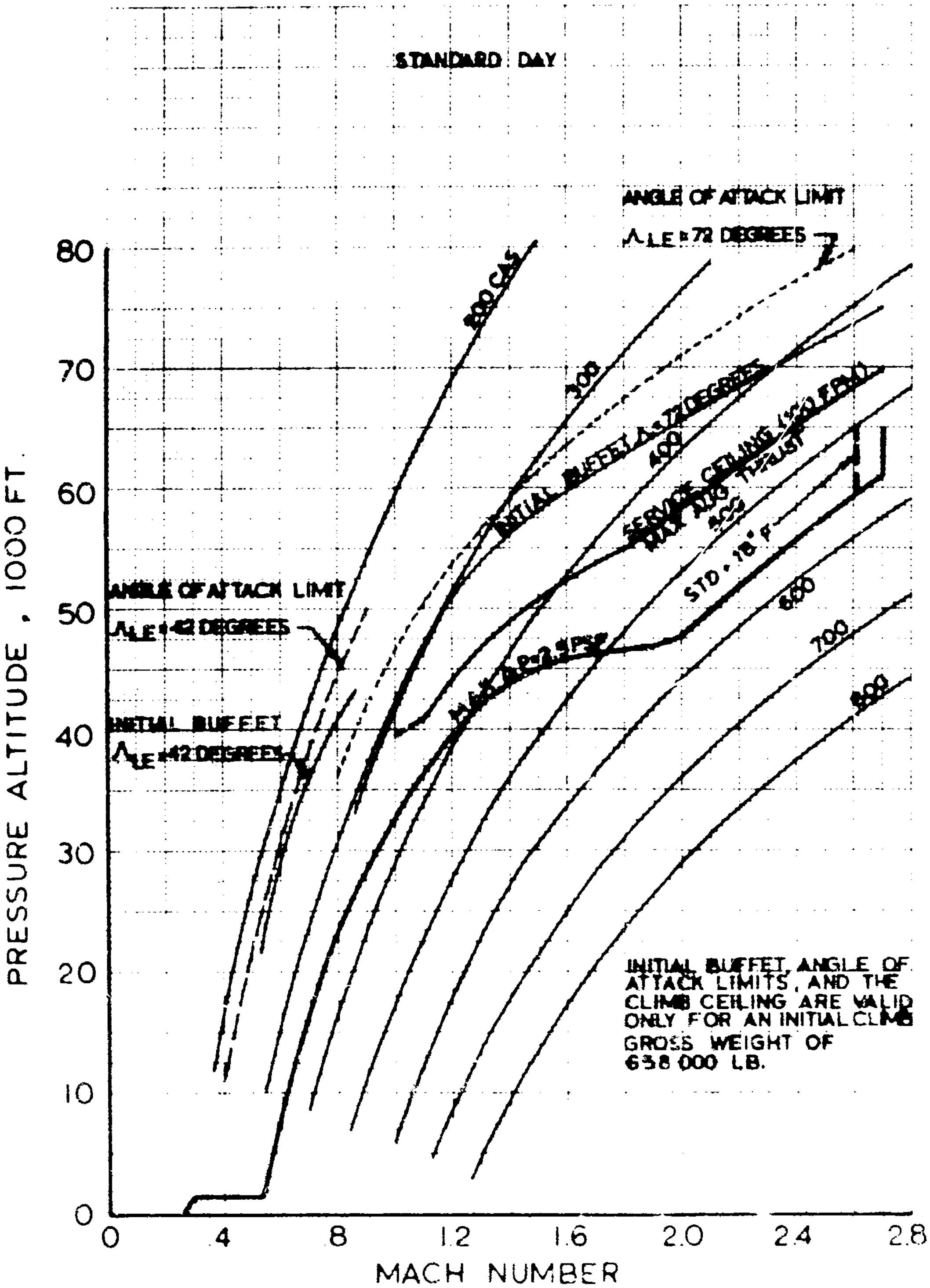


Figure 2-23. Maximum ΔP 2.5 PSF Climb Schedule

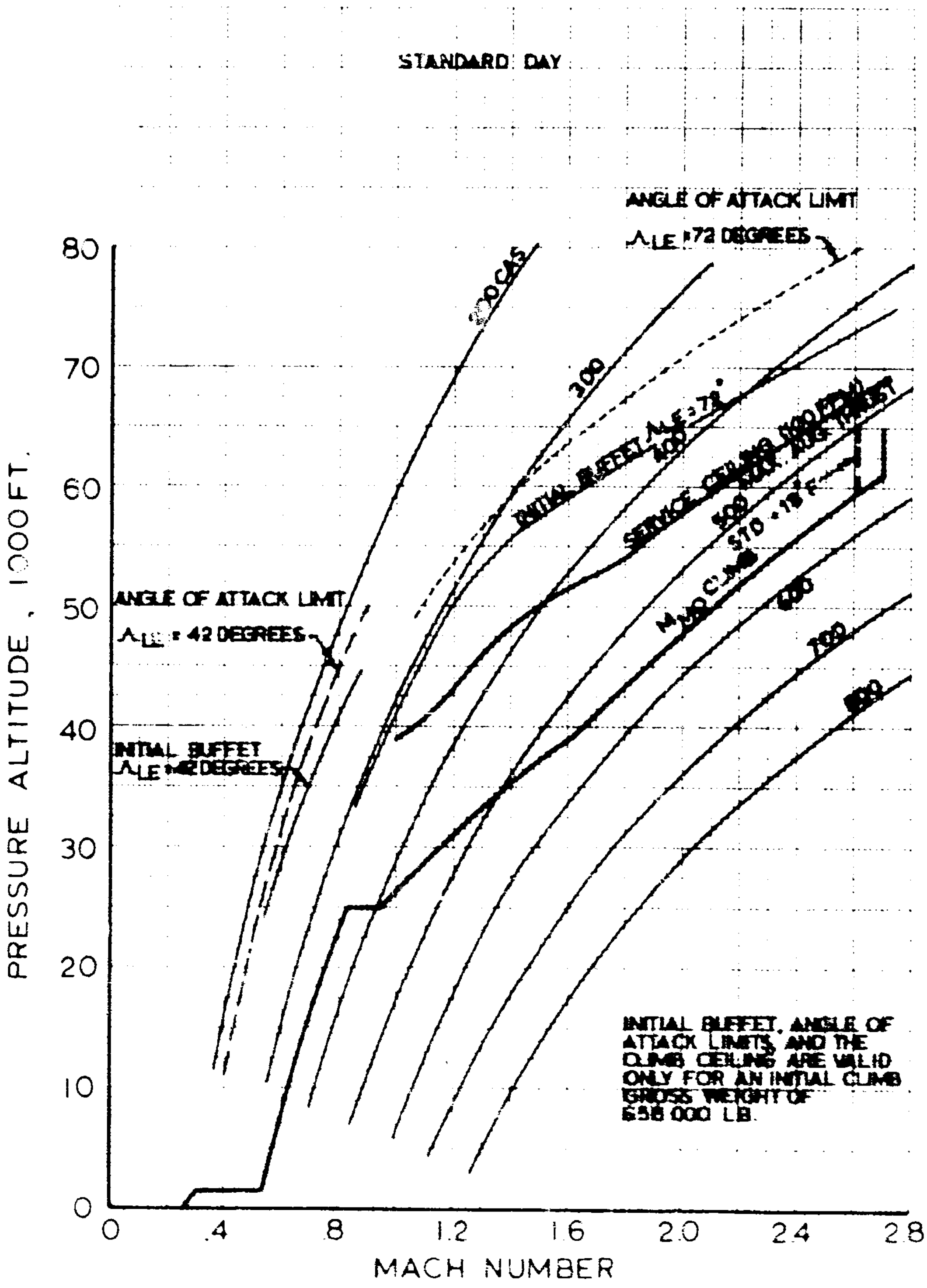


Figure 2-24. V_{MO} M_{MO} Climb Schedule

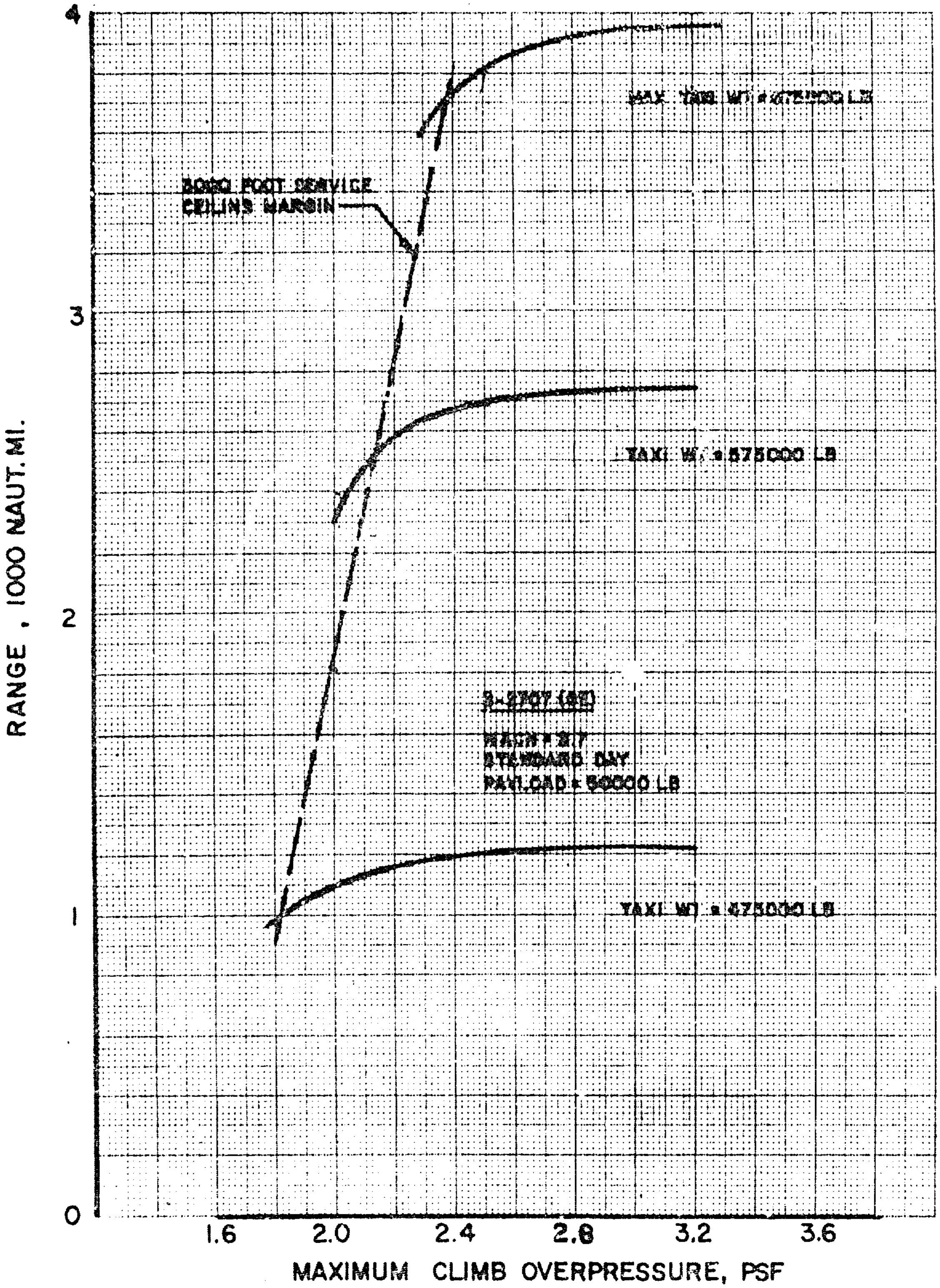


Figure 2-25. Effect of Maximum Climb Overpressure on Range

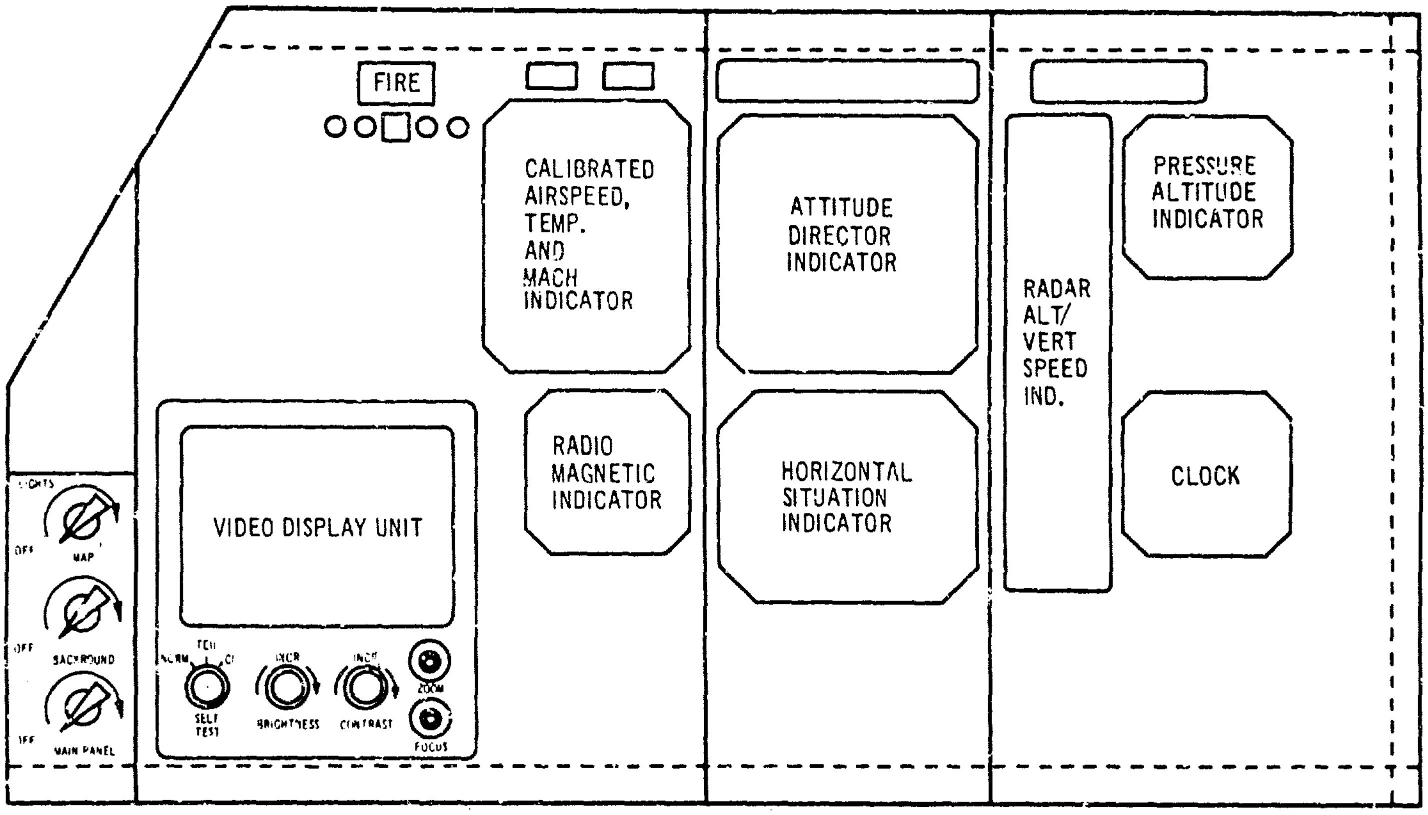


Figure 2–26. Captain's Instrument Panel

data system and indicates a dot of "present position" on a Mach-Altitude plot similar to Figs. 2-26 and 2-27. The Δ P line to be flown is generated on the display as well as significant speed and ceiling placards. The display may be time-shared on a TV scope. The dot has a line through it to indicate the Mach-altitude rate as a vector. Flight simulations using such a display have proven its usefulness.

Improved pitch attitude indicators are being developed to increase the pitch attitude resolution for better manual control during climb, cruise, and descent. An increase in pitch attitude sensitivity (by a factor of 10) on a cathode ray tube (CRT) in the simulator markedly increases the pilot's controllability. This is particularly beneficial with SAS off where the pitch response is slow and lightly damped at the high-altitude cruise condition.

A suitable map display is under study to further improve the operational efficiency of the flight crew, particularly during climb and descent. The map display presents integrated position information from the inertial navigation and the VOR/DME systems. The ability to precisely navigate the airplane, particularly for off-course and parallel course routing, is of considerable importance. The map display expedites arrivals and departures and also allows closer control of flight over areas sensitive to sonic boom. The map display will also allow precise ILS "turn-ons," thus improving terminal area traffic control efficiency as well as airplane management by the flight crew.

2.5.3 Placards

The airplane maximum operating and maximum design placards, along with wing-sweep placards for the climb, cruise, and descent, are shown in Fig. 2-28. Since the airplane has considerable thrust and acceleration capability at the lower altitude, it is important to adequately protect the airplane from inadvertent overspeed. A V_{MO}, T_{MO}, and M_{MO} pointer ("barber pole") is on the airspeed indicators. In addition to speed, temperature, and altitude these limit indications will be geared to the actual sweep angle so that the applicable V_{MO}, T_{MO}, or M_{MO} is always displayed to the pilot. An aural warning will be installed to warn of an overspeed condition. The warning system also senses roll and attitude pitch rates as well as speed rates in order to

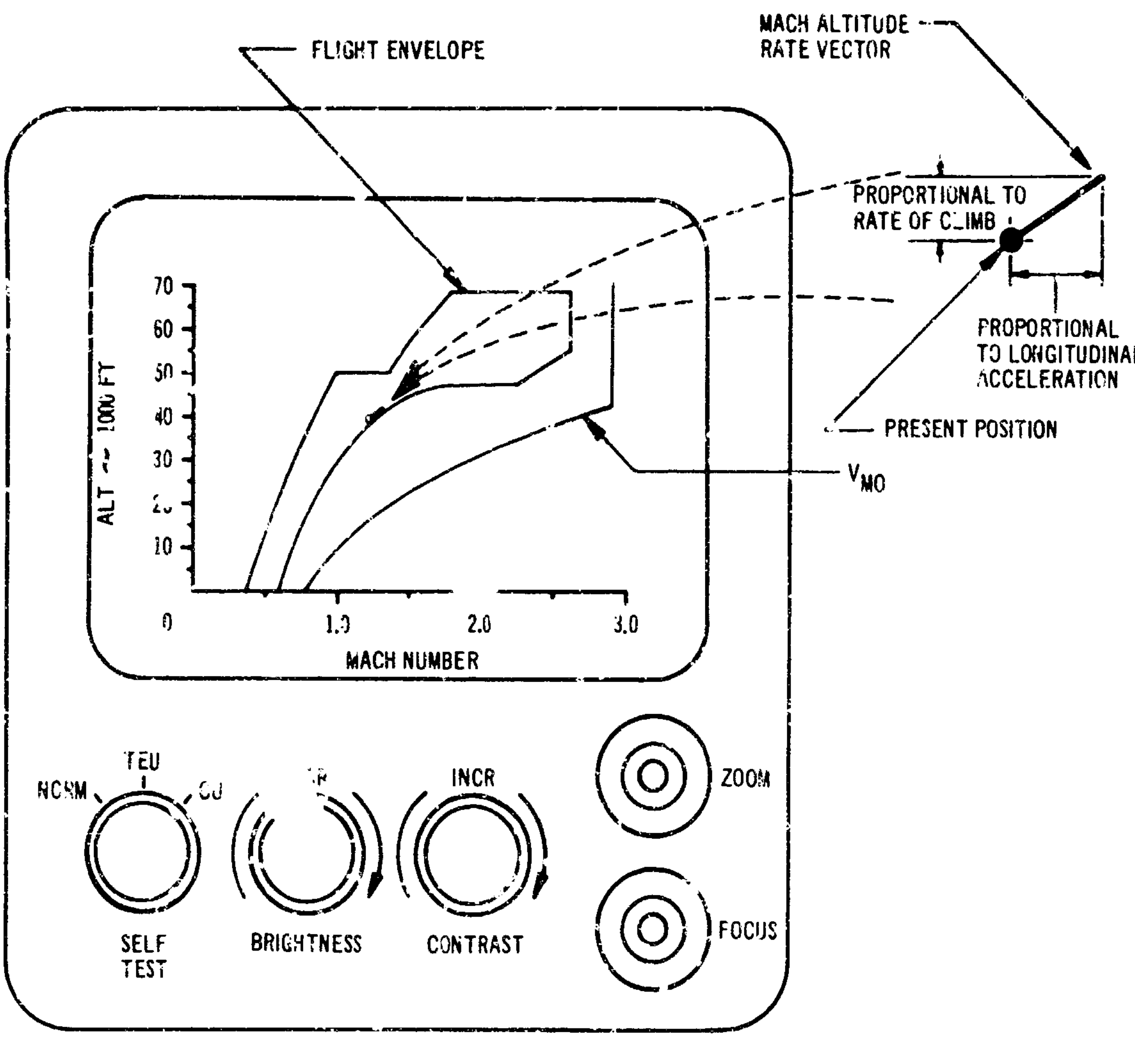


Figure 2-27. Mach-- Altitude Display

provide anticipatory warning of an incipient overspeed condition. The wing speed and flap placards are as follows:

Wing Sweep Angle, Deg	Wing Flap Position, Deg	Sea Level Placard (Knots CAS)
30	5/[illegible]	290
30	20/40	225
30	30/50	195
42	0	350
72	0	375

The service ceiling limit shown in Figs. 2-23 and 2-24 defines airplane performance capability (100 fpm rate of climb) for the climb weight resulting from a maximum gross weight takeoff. The initial buffet boundary below approximately Mach 0.9 is the minimum usable flying speed in the conventional sense. Above Mach 0.9, at the buffet boundary, the airplane could be in buffet but would have the capability of developing a significantly higher lift coefficient. The normal climb profile clears all buffet boundaries by 5,000 ft and ceiling limits by at least 4,000 ft.

2.5.4 Climb and Acceleration Procedures

An operational schedule for the maximum gross

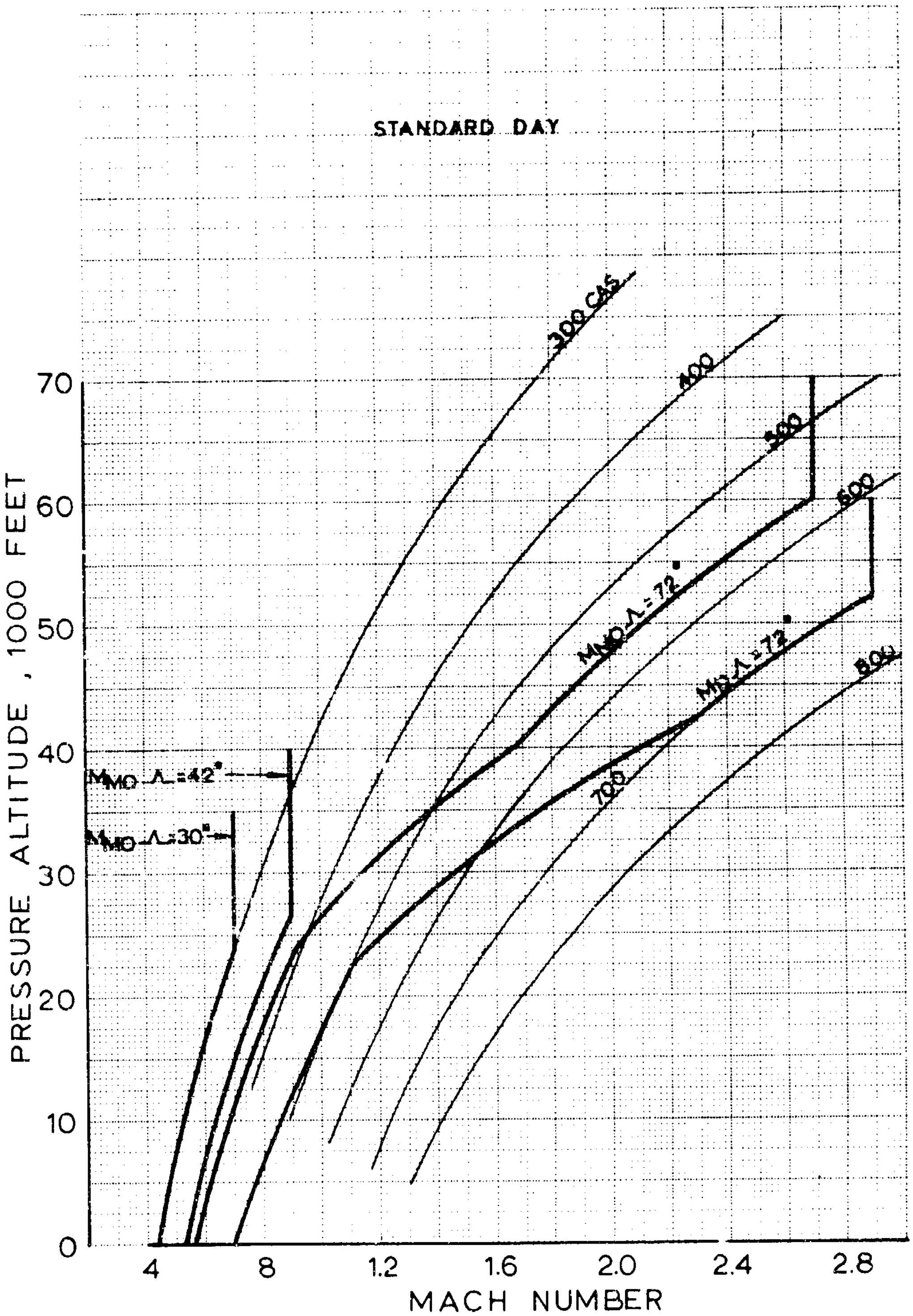


Figure 2–28. Speed Placards

weight climb and acceleration phase of the flight is shown in Fig. 2-23. At approximately 1,500 ft and as soon as practical after takeoff flaps have been retracted and the wings swept to 42 deg, the pilot sets maximum dry thrust. The airplane accelerates to 350 knots CAS and maintains this airspeed during the climb to 25,000 ft. At Mach 0.85 (26,000 ft), the wings are swept to 72 deg in order to operate at the maximum lift-to-drag ratio (L/D) over a large range of speeds. This provides the optimum climb, acceleration, and cruise capability. The forebody is also raised to the full up position at this point. As the aircraft approaches Mach 0.95 (30,500 ft), maximum augmented thrust is applied. The airplane climb angle is reduced slightly at approximately 40,000 ft to accelerate along the 2.5 psf sonic boom speed schedule. The desired overpressure limit speed schedule is followed out to approximately 560 knots CAS (47,500 ft), which is the climb speed until initial cruise altitude is reached. The climb speed schedules are not greatly affected by gross weight. The initial climb to approximately 30,000 ft is the same CAS for all gross weights in any sonic boom limited climb. The final segment is also unchanged except for the cruise level-off altitude. Only the sonic boom limited portion of the climb changes with gross weight.

2.5.5 Climb Performance
When sonic boom restrictions do not apply, such as over water, a range advantage can be realized by sweeping the wing to 72 degrees as soon as practical after flap retraction and following the V_{MO}/M_{MO} climb schedule. Maximum augmented thrust is applied just prior to transonic acceleration. For the B-2707 (GE) maximum gross weight mission (3,819 nmi), flying the M_{MO} climb schedule rather than the maximum $\Delta P = 2.5$ psf climb schedule, would increase the overall range 131 nmi or reduce the block time by 5 minutes.

On a "hot day," for a given sonic boom overpressure level, the airplane should accelerate at the same tapeline altitude as on the standard day. Therefore, during above standard day temperatures, the airplane is flown at an indicated altitude that is the same tapeline height as the standard day pressure altitude during the sonic boom limited segment. The overall mission "hot day" range adjustment is discussed in Par. 2.6.1.

A rate-of-climb and body-attitude profile for ΔP max = 2.5 psf climb schedule is shown in Fig. 2-29. Additional climb performance for

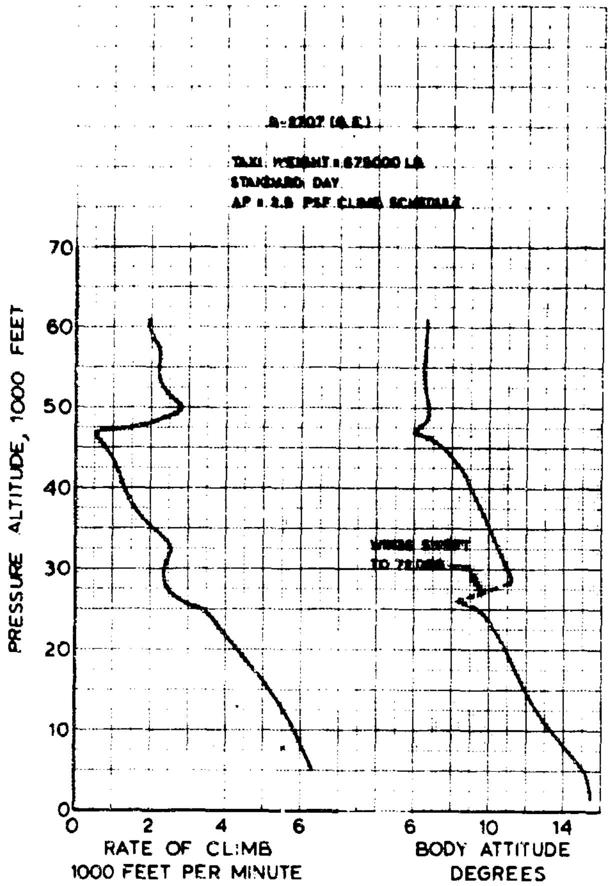


Figure 2-29. Rate of Climb and Body Attitude Profile

subsonic and supersonic climb is shown in Figs. 2-30 and 2-31.

2.5.6 Handling Characteristics
Longitudinal trim is easily maintained throughout the climb profile (including wing-sweep sequence) using the trim button as needed or with SAS on, trim is maintained automatically. The SAS system provides adequate damping and improved airplane response at the higher altitudes and speeds. The SAS also provides essentially a stick-steering capability in that it tends to hold the airplane in any given attitude until a pilot command is inserted. The longitudinal trim changes during acceleration and wing sweep are not large and are easily handled with SAS off.

2.6 CRUISE

2.6.1 Supersonic Cruise Procedures and Profiles
The B-2707 cruises at Mach 2.7, or 500°F stagnation temperature, whichever occurs first. The

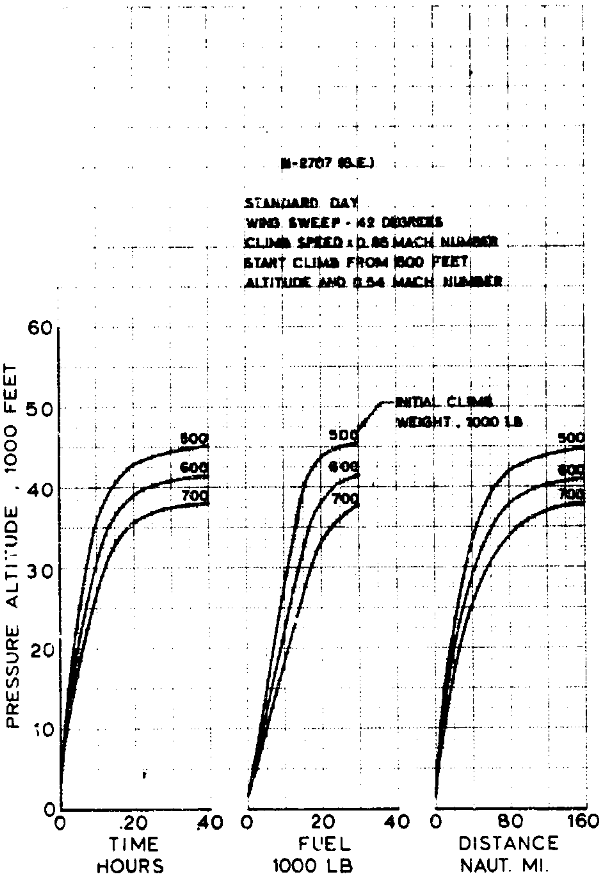


Figure 2-30. Subsonic Climb Performance

cruise airspeed is 1,550 knots TAS (558 knots CAS). Partial thrust augmentation is required for most of the supersonic cruise missions.

The piloting techniques required during supersonic cruise are similar to those used during subsonic conditions. The Mach hold mode of the auto-throttle is available to assist the pilot in cruise control when desired. In this mode, the thrust levers are positioned by the auto-throttle system to match engine thrust to the desired cruise condition.

Supersonic mission profiles are shown for the maximum gross weight B-2707 in Figs. 2-32 and 2-33. The profiles are shown utilizing a cruise climb procedure for supersonic cruise. This procedure under idealized conditions would require no thrust changes during the cruise. The thrust setting at initiation of cruise would cause the airplane to climb at a rate of approximately 50 fpm. By using the autopilot in the rate of climb mode, the airplane will fly a profile defining best-cruise-altitude for a given mission. Two alternate cruise procedures are shown in Fig. 2-34.

The total mission range, shown as cruise procedure A is 3,819 nmi (Fig. 2-34). A range loss of approximately 1.1 percent results from using an optimized constant altitude with a step climb procedure (cruise B). A range loss of 2.2 percent results from an optimized constant altitude cruise procedure (cruise C).

The effect of temperature, altitude deviation, and wind on range is shown in Figs. 2-35 and 2-36. The cruise range change with deviation from best-cruise-altitude plot shown in Fig. 2-35 indicates that the B-2707 would be fairly insensitive to small altitude variations during cruise. The small range reductions shown are for an altitude deviation for the entire cruise portion of the mission. It is also shown that the best cruise altitude covers a band of approximately ±500 ft.

During operation at above standard temperatures, the B-2707 flies at a reduced Mach number so as not to exceed a 500° F stagnation temperature limit. An adjustment is provided on the auto-throttle Mach hold system for this condition. If the complete mission shown in Fig. 2-32 were flown in standard +18° F conditions, the total range would be reduced by 369 nmi (9.7 percent range reduction). It should be noted (Fig. 2-36) that in the case of the hot-day mission, approximately 72 percent of the range loss is during the cruise condition. The values shown in this figure are based on a pilot's typical-mission plan for standard day conditions and the actual flying of the complete mission in a standard +18° F environment. For the pilot to fly to his original destination, he would be required to use 38 percent of his reserve fuel. As shown in Fig. 2-37, a standard +18° F condition at altitude is very unusual. A hot-day at both altitude and sea level seldom occurs.

Typical average fuel flow during supersonic cruise is 25,000-lb/hour/engine. Fuel management is comparable to current jet transports. Normal fuel management consists of using all the auxiliary tank fuel (1A, 4A, forward, and aft auxiliary), and then main tank fuel (1, 2, 3, and 4) for the remainder of the flight. Figures 2-38 and 2-39 show the sequence of fuel management for typical missions. No transfer is required to prep. e for slowing down to subsonic flight. Fuel temperatures will be monitored in a manner similar to existing prac-

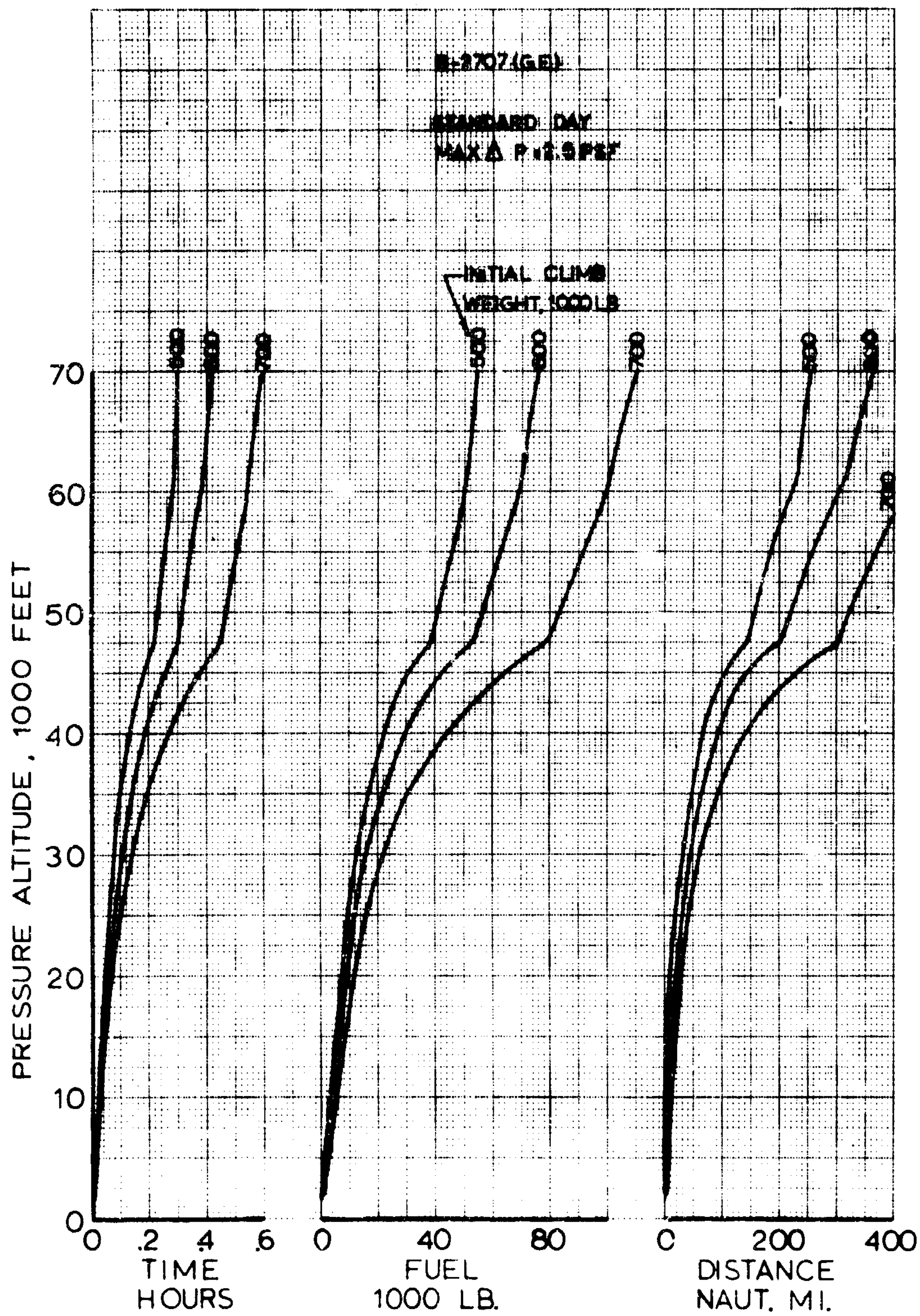
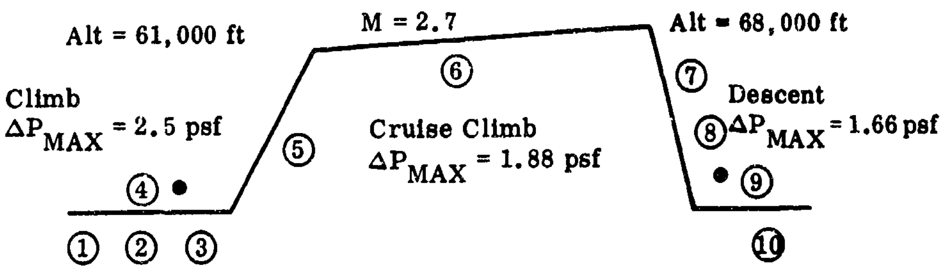


Figure 2-31. Climb Performance (Max. ΔP = 2.5 PSF Schedule)

Max. Design
Taxi Weight = 675,000 lb
OEW = 287,500 lb
Payload = 50,000 lb
Wing Area = 9,000 ft^2
Engine = GE4/J5P
Airflow = 600 lb/sec

Std. Day, Zero Wind
Phase III Rules
Block Time = 3.319 hr
Block Fuel = 292,181 lb



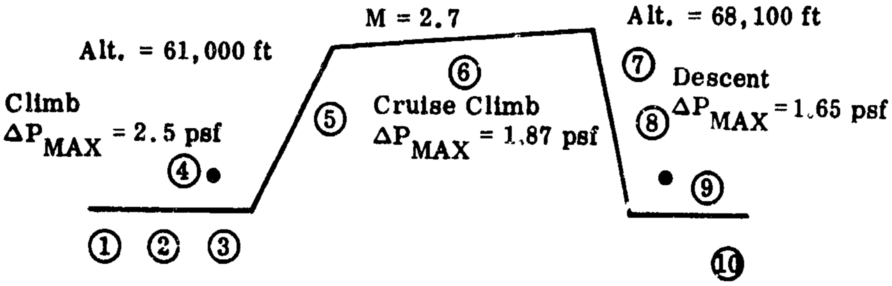
		Fuel Burned, (lb)	Fuel Remaining, (lb)	Weight at End of Operation, (lb)	Time, (hr)	Distance, (nmi)
1.	Taxi Out	4,060	333,440	670,940	0.167	--
2.	Take Off (S.L. to 35 ft)	4,150	329,290	666,790	0.010	--
3.	Acceleration to Climb Speed	4,790	324,500	662,000	0.024	5.0
4.	Departure Air Maneuver (250 kn EAS and 5,000 ft)	4,000	320,500	658,000	0.067	--
5.	Acceleration and Climb	86,200	234,300	571,800	0.467	381
6.	Supersonic Cruise Climb	181,991	52,309	389,809	2.085	3,227
7. & 8.	Deceleration & Descent (Cruise Alt to 1,500 ft)	2,330	49,979	387,479	0.333	206
9.	Destination Air Maneuver (Approach & Landing Allowance, 250 kn EAS at 5,000 ft). WT = WT at (8) – 5% block fuel	2,940	47,039	384,539	0.083	--
10.	Taxi In	(1,720)*			0.083	--
	TOTAL MISSION	290,461			3.319	3,819
Reserves						
A.	5% Block Fuel	14,609		369,930		
B.	Missed Approach (Climb S.L. to 1,500 ft)	2,510		367,420		
C.	Climb from 1,500 ft subsonic cruise, descend to S.L. at alternate (300 st mi)	20,070		347,350		
D.	20 min hold at 15,000 ft over alternate	9,850		337,500		
TOTAL RESERVES		47,039				
TOTAL FUEL		337,500				

*Fuel burned not included in mission fuel; for D.O.C. only

Figure 2-32. B-2707 (GE) Intercontinental Supersonic Mission

Max. Design
Taxi Weight = 675,000 lb
OEW = 285,000 lb
Payload = 50,000 lb
Wing Area = 9,000 ft²
Engine = PWA JTF17A-21B
Airflow = 687 lb/sec

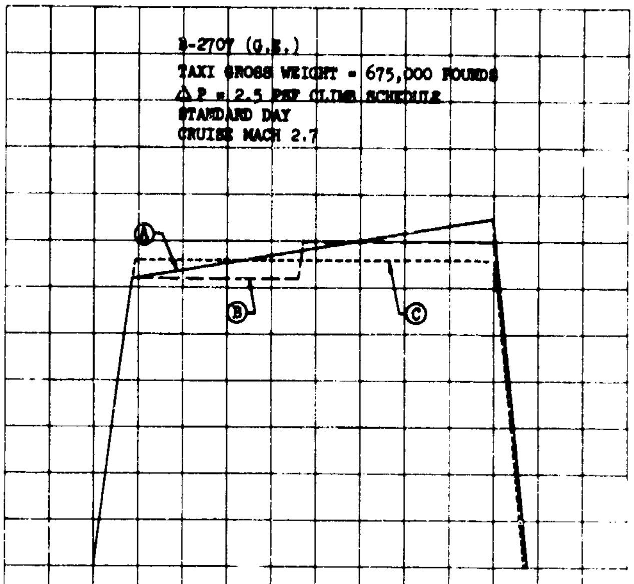
Std. Day, Zero Wind
Phase III Rules
Block Time = 3.352 hr
Block Fuel = 298,162 lb



		Fuel Burned, lb	Fuel Remaining lb	Weight at End of Operation, lb	Time, hr	Distance, nmi
1.	Taxi Out	2,940	337,060	672,060	0.167	--
2.	Take Off (S.L. to 35 ft)	4,476	332,584	667,584	0.010	--
3.	Acceleration to Climb Speed	4,982	327,602	662,602	0.043	10
4.	Departure Air Maneuver (250 kn EAS and 5,000 ft)	3,225	324,377	659,377	0.067	--
5.	Acceleration and Climb	94,875	229,502	564,502	0.558	412
6.	Supersonic Cruise Climb	182,094	47,408	382,408	2.015	3,120
7. & 8.	Deceleration and Descent (Cruise Alt to 1,500 ft)	2,010	45,398	380,398	0.326	196
9.	Destination Air Maneuver (Approach and Landing Allowance, 250 kn EAS at 5,000 ft). WT = WT at (8) - 5% block fuel	2,280	43,118	378,118	0.083	--
10.	Taxi In	(1,780)*			0.083	--
	TOTAL MISSION	296,882			3.352	3,738
Reserves						
A.	5% Block Fuel	14,908		363,210		
B.	Missed Approach (Climb S.L. to 1,500 ft)	2,230		360,980		
C.	Climb from 1,500 ft subsonic cruise, descend to S.L. at alternate (300 st mi)	18,010		342,970		
D.	20 min hold at 15,000 ft over alternate	7,970		335,000		
TOTAL RESERVES		43,118				
TOTAL FUEL		340,000				

*Fuel burned not included in mission fuel; for D.O.C. only

Figure 2-33. B-2707 (P&WA) Intercontinental Supersonic Mission



CRUISE PROFILE	TOTAL MISSION RANGE	DEVIATION OF TOTAL MISSION RANGE FROM OPTIMUM CRUISE CLIMB
(A) Optimum Cruise Climb	3819 N. Mi.	——
(B) Constant Altitude with 4000 Ft. Step Climb	3776 N. Mi.	-43 N. Mi.
(C) Optimum Constant Altitude	3735 N. Mi.	-84 N. Mi.
(C) Plus 2000 Ft.	3729 N. Mi.	-90 N. Mi.
(C) Minus 2000 Ft.	3673 N. Mi.	-146 N. Mi.

Figure 2-34. Supersonic Cruise Procedures

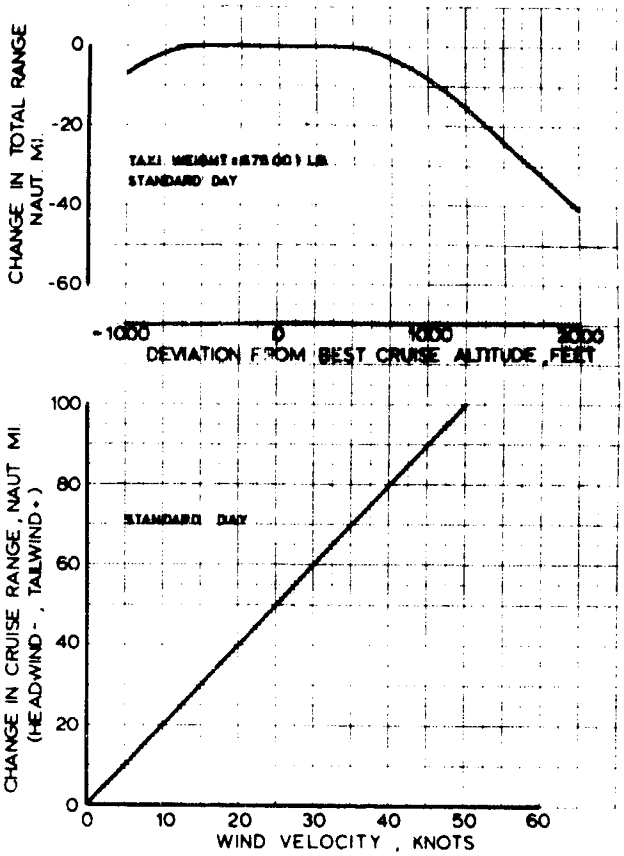


Figure 2-35. Off Design Range Effects

tice, except the normal change will be a temperature rise, rather than drop. In the event of a malfunction causing abnormal fuel temperature rise, the situation can normally be rectified by slowing down.

2.6.2 Subsonic Cruise Procedures

The long-range subsonic cruise speed is Mach 0.85 with a wing-sweep angle of 42°. The B-2707 (GE) at maximum taxi weight, flown subsonically for the complete mission, has a range of 3,286 nmi. The B-2707 (P&WA) at the same taxi weight, flying a completely subsonic mission, has a range of 3,870 mi. The procedures used for subsonic cruise are the same as used on current jet transports.

2.6.3 Cruise Flexibility

The B-2707 is compatible with the traffic control requirement of sonic boom restriction areas and traffic conditions which require subsonic operation. Consequently, the B-2707 is adaptable to varying route structures.

The B-2707 (GE) range trades for split missions (part subsonic and part supersonic) are shown on Fig. 2-40. The range reduction for a 400-nmi subsonic leg at the beginning of the mission is 63 nmi (1.6 percent of the total range). A subsonic leg of equal distance at the end of the mission will result in a slightly larger range reduction of 104 nmi (2.7 percent reduction).

The B-2707 (P&WA) range trades for split missions are shown in Fig. 2-41. The complete mission range is unchanged with a 400-nmi subsonic leg at the beginning of the mission. A range reduction of 40 nmi (1.1 percent range reduction) will result when a 400-nmi subsonic leg is flown at the end of the mission.

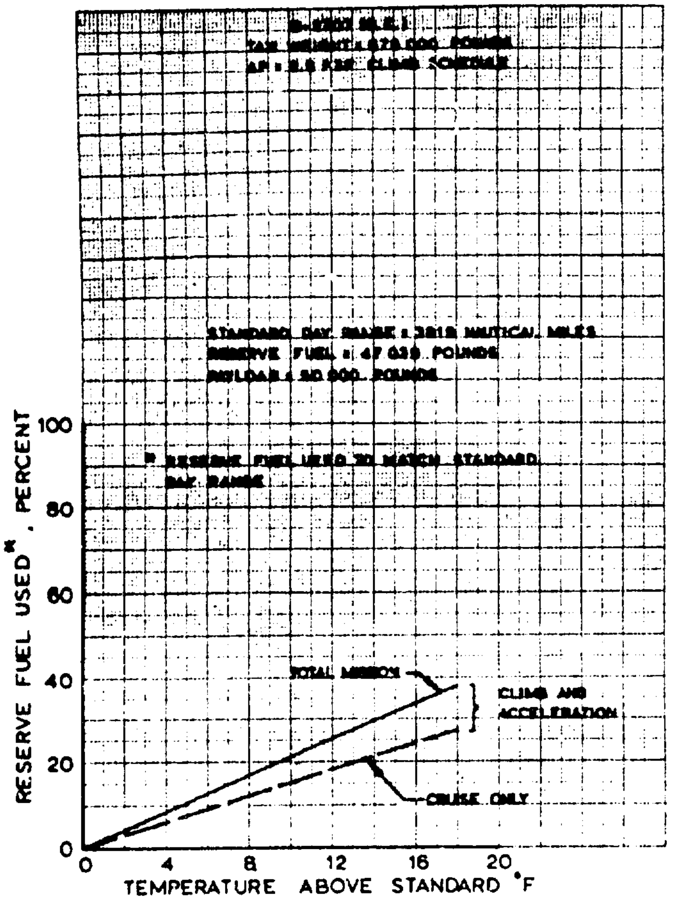


Figure 2-36. Effect of Non-Standard Temperature on Range

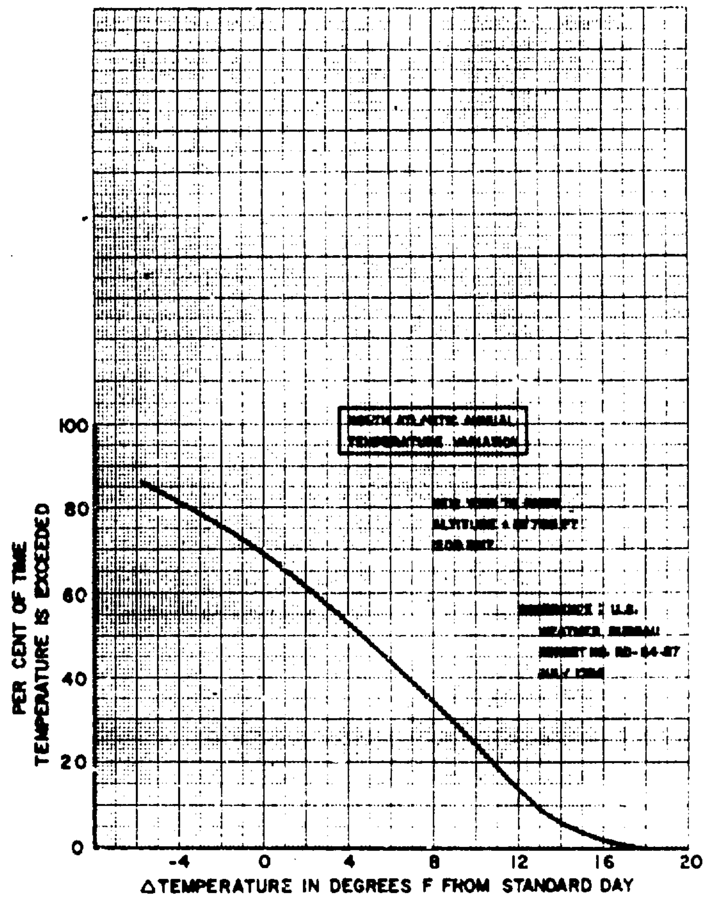


Figure 2-37. North Atlantic Annual Temperature Variation

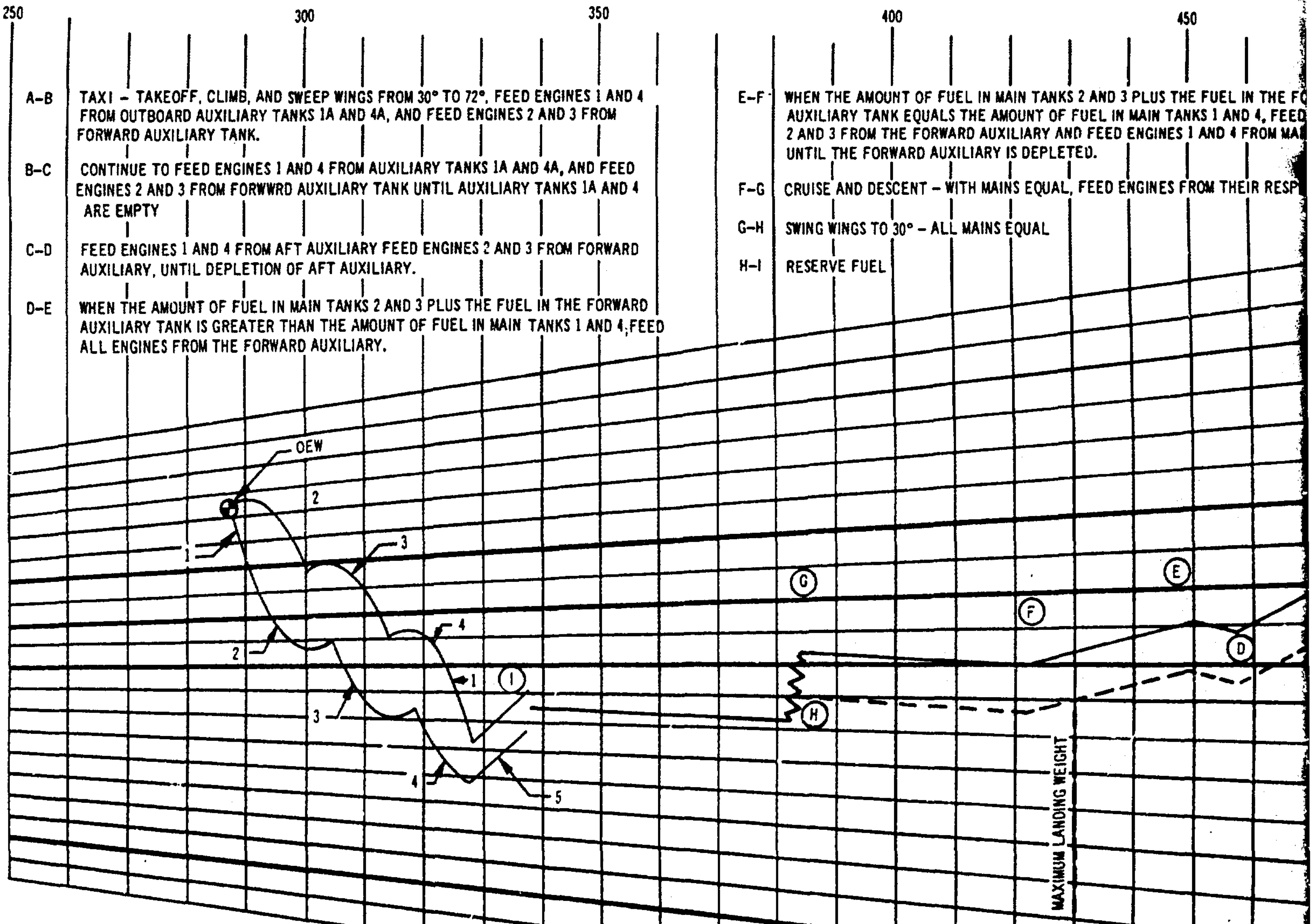
A summary of B-2707 performance data may be found in Airplane Performance, V2-B2707-4, (GE engines) and Airplane Performance, V2-B2707-5, (P&WA engines).

The B-2707 has excellent domestic operational capabilities. By flying an initial subsonic leg of approximately 900 nmi, a mission can be accomplished without exceeding an overpressure of 2psf during climb and 1.5psf during cruise at Mach 2.7. The initial gross weight for such a mission is 600,000 lb and the total range is 2,525 nmi. The zero range loss portion of the curves shown in Figs. 2-40 and 2-41 represent the normal distance increment included in the supersonic mission range (3,819nmi, GE or 3,738nmi, P&WA) from liftoff to Mach 1.0 in climb or from Mach 1.0 in descent to touchdown. The subsonic leg shown in these figures is a combination of the climb or descent distance dscribed above as well as a subsonic cruise portion.

2.6.4 Mid-Point Failures and Emergencies

2.6.4.1 Propulsion Failure

The airplane can be controlled easily with inlet unstart combines with an engine failure in supersonic flight - even with maximum augmented thrust, which could occur in a final climb segment (V_{MO}/M_{MO} 560 CAS at Mach 2.7). The pilot or the autopilot can control the situation using moderate elevon deflections. With SAS off, the pilot's control inputs are larger for the failed engine case but control is maintained with elevon alone. Credit is not taken for rudder input by the pilot because the sideslip or yaw angles are small and the roll angles are more easily perceived. A failed engine is placed in the "windmill braked" configuration during supersonic flight to prevent overheating. A stator row is positioned to shut off the air flow through the engine. At subsonic speeds, the engine is allowed to windmill for minimum drag.



PAYLOAD

PASSENGERS AT 165 LB EACH
BAGGAGE 35 LB/PASSENGER

		SEATS UTILIZED	SEATS AVAILABLE
1	FIRST CLASS	27	30
2	TOURIST – WINDOW SESTS	83	83
3	TOURIST – AISLE SEATS	83	83
4	TOURIST – REMAINING SEATS	57	81

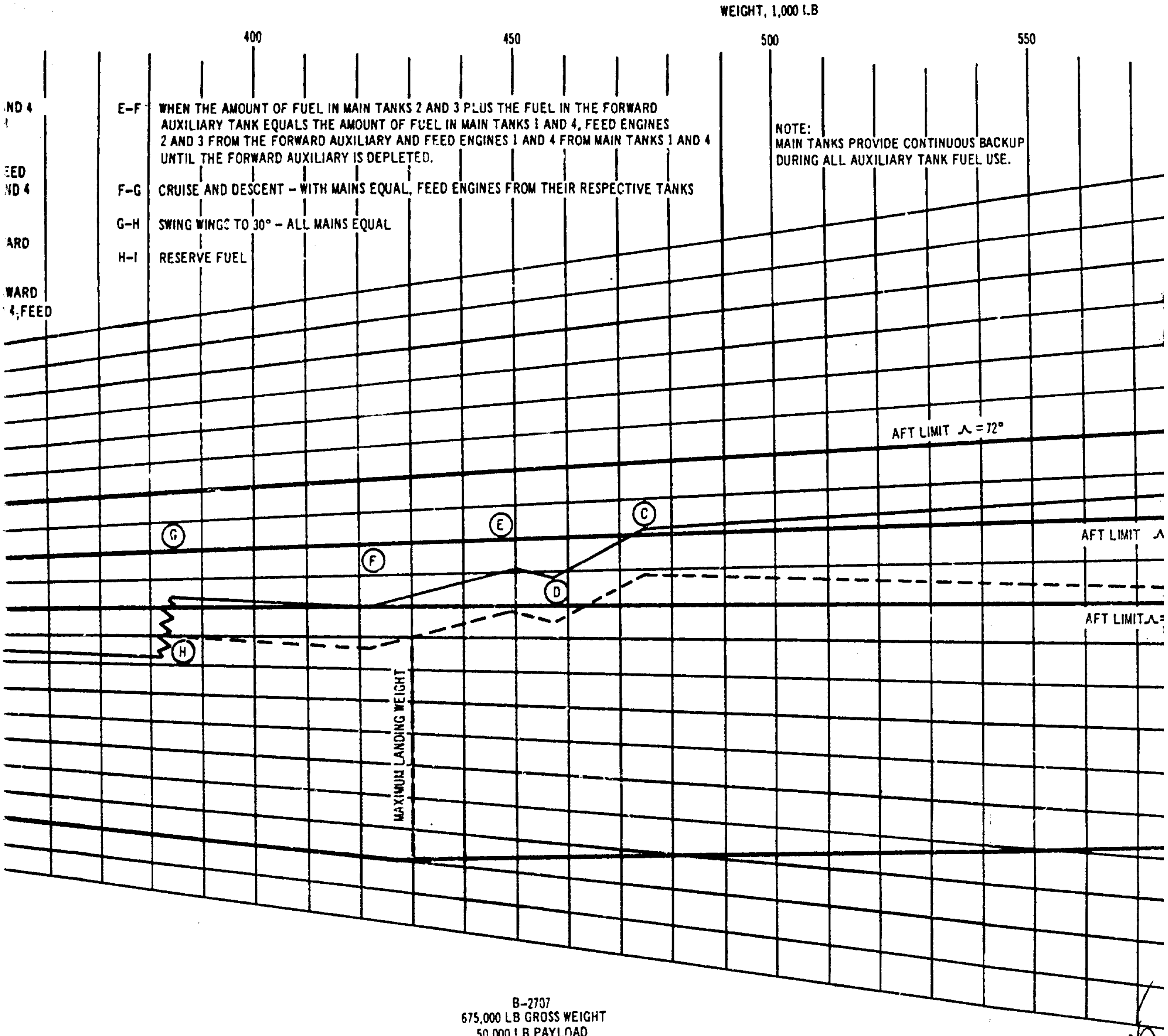
CARGO BASED ON 10 PCF

5	AFT CARGO, LB	8750	12,040
	FORWARD CARGO, LB.	–0–	19,320

B–2707
675,000 LB GROSS WEIGHT
50,000 LB PAYLOAD

THE WING REFERENCE CHORD IS 1896.7 IN WITH THE LEADING EDGE AT BODY STATION 1440.

A



WEIGHT, 1,000 LB
400
450
500
550
ND 4
EED
ND 4
ARD
WARD
4,FEED
E–F WHEN THE AMOUNT OF FUEL IN MAIN TANKS 2 AND 3 PLUS THE FUEL IN THE FORWARD AUXILIARY TANK EQUALS THE AMOUNT OF FUEL IN MAIN TANKS 1 AND 4, FEED ENGINES 2 AND 3 FROM THE FORWARD AUXILIARY AND FEED ENGINES 1 AND 4 FROM MAIN TANKS 1 AND 4 UNTIL THE FORWARD AUXILIARY IS DEPLETED.
F–G CRUISE AND DESCENT – WITH MAINS EQUAL, FEED ENGINES FROM THEIR RESPECTIVE TANKS
G–H SWING WINGS TO 30° – ALL MAINS EQUAL
H–I RESERVE FUEL
NOTE:
MAIN TANKS PROVIDE CONTINUOUS BACKUP DURING ALL AUXILIARY TANK FUEL USE.
AFT LIMIT Λ = 72°
AFT LIMIT Λ
AFT LIMIT Λ
C
E
G
F
D
H
MAXIMUM LANDING WEIGHT
B-2707
675,000 LB GROSS WEIGHT
50,000 LB PAYLOAD

!0.

Figure 2–38.

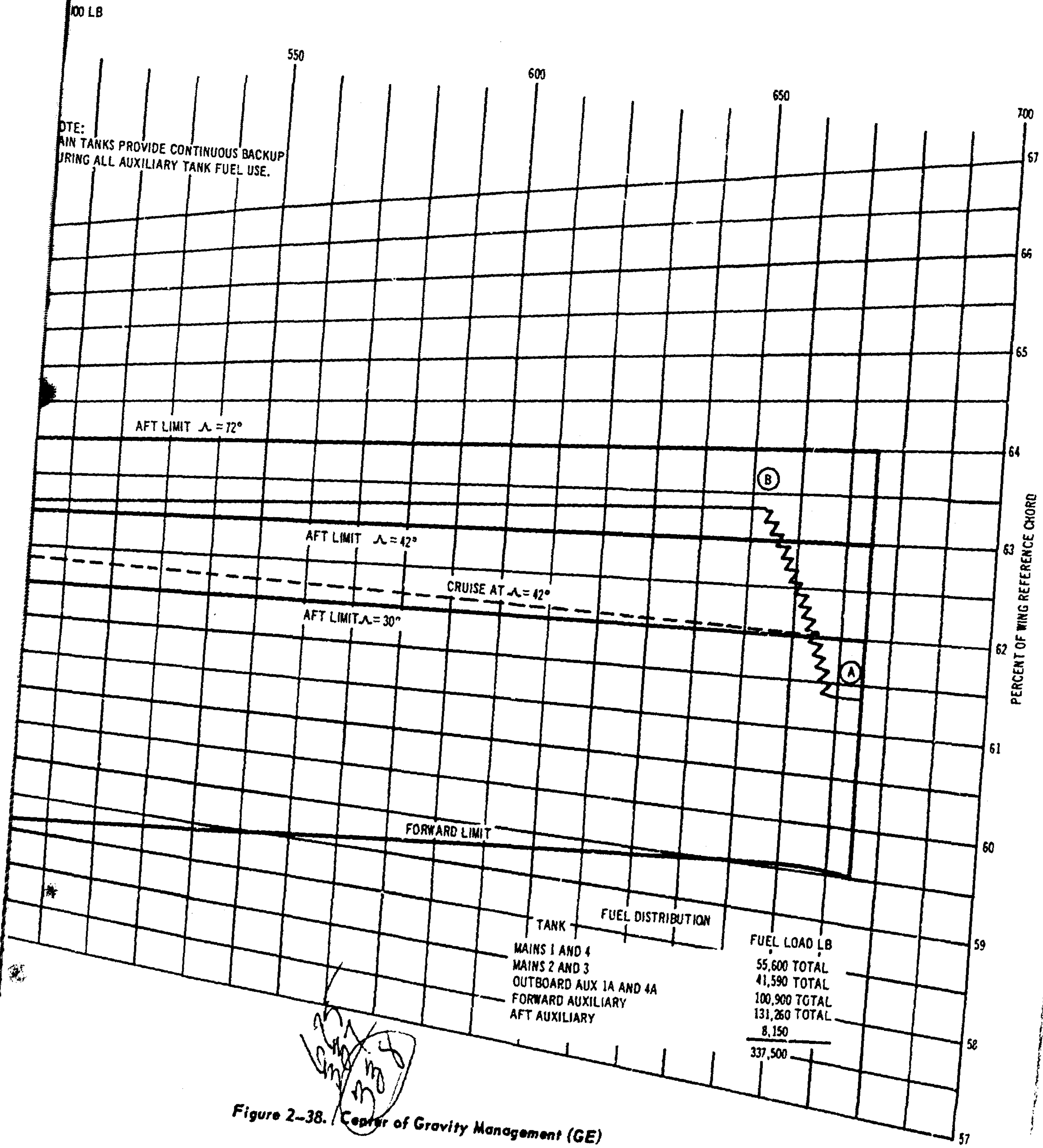
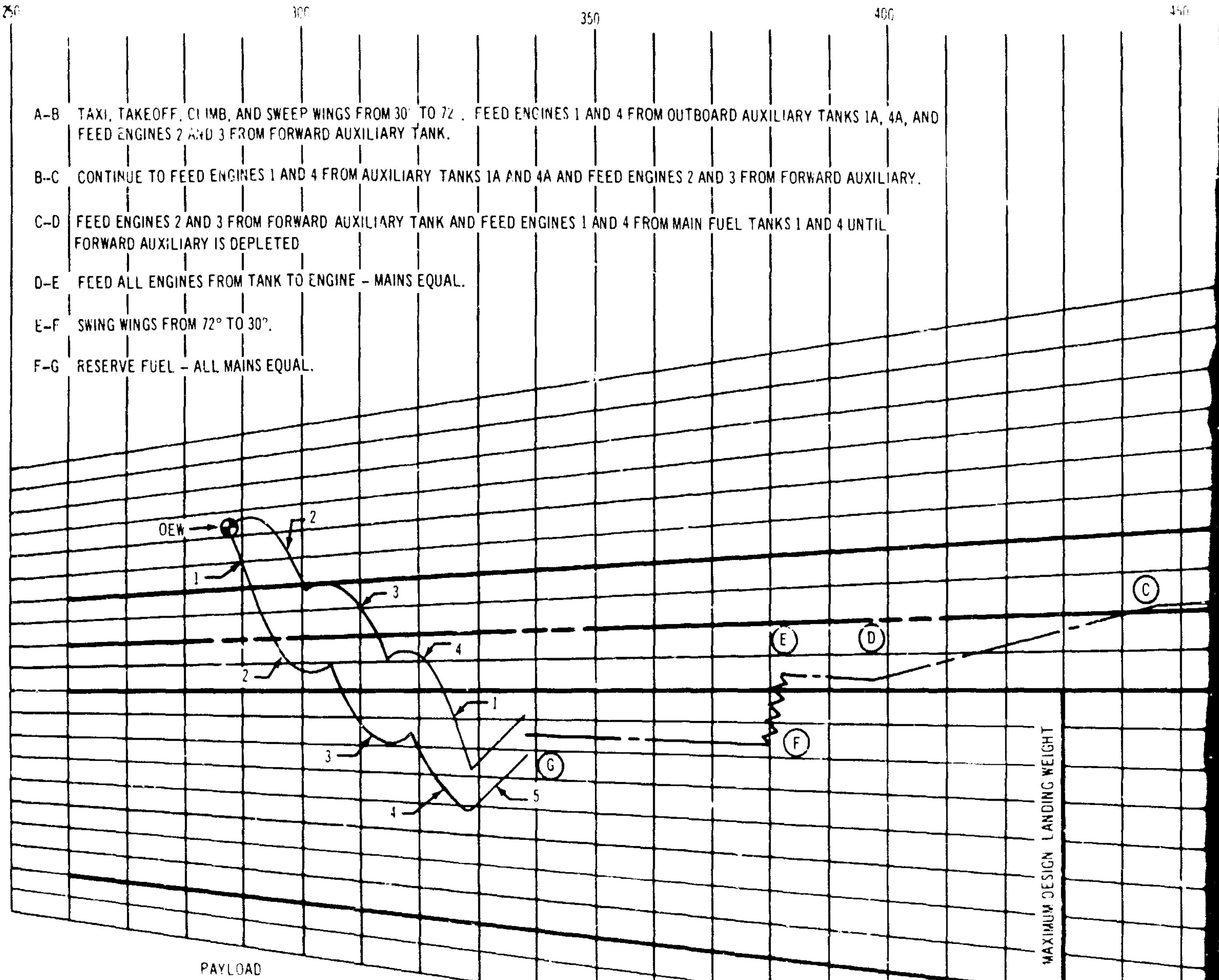


Figure 2-38. Center of Gravity Management (GE)



PASSENGERS AT 165 LB EACH
BAGGAGE 35 LB PASSENGER

	SEATS UTILIZED	SEATS AVAILABLE
1 FIRST CLASS	[illegible]	[illegible]
2 TOURIST – WINDOW SEATS	[illegible]	53
3 TOURIST – AISLE SEATS	53	53
4 TOURIST – REMAINING SEATS	5[illegible]	51

CARGO BASED ON [illegible] LB P.C.F

5 AFT CARGO LB	[illegible]	[illegible]
FORWARD CARGO LB	[illegible]	[illegible]

B–[illegible]

[illegible] LB GROSS W
[illegible] LB PAYLOA
[illegible] LB FUEL

A

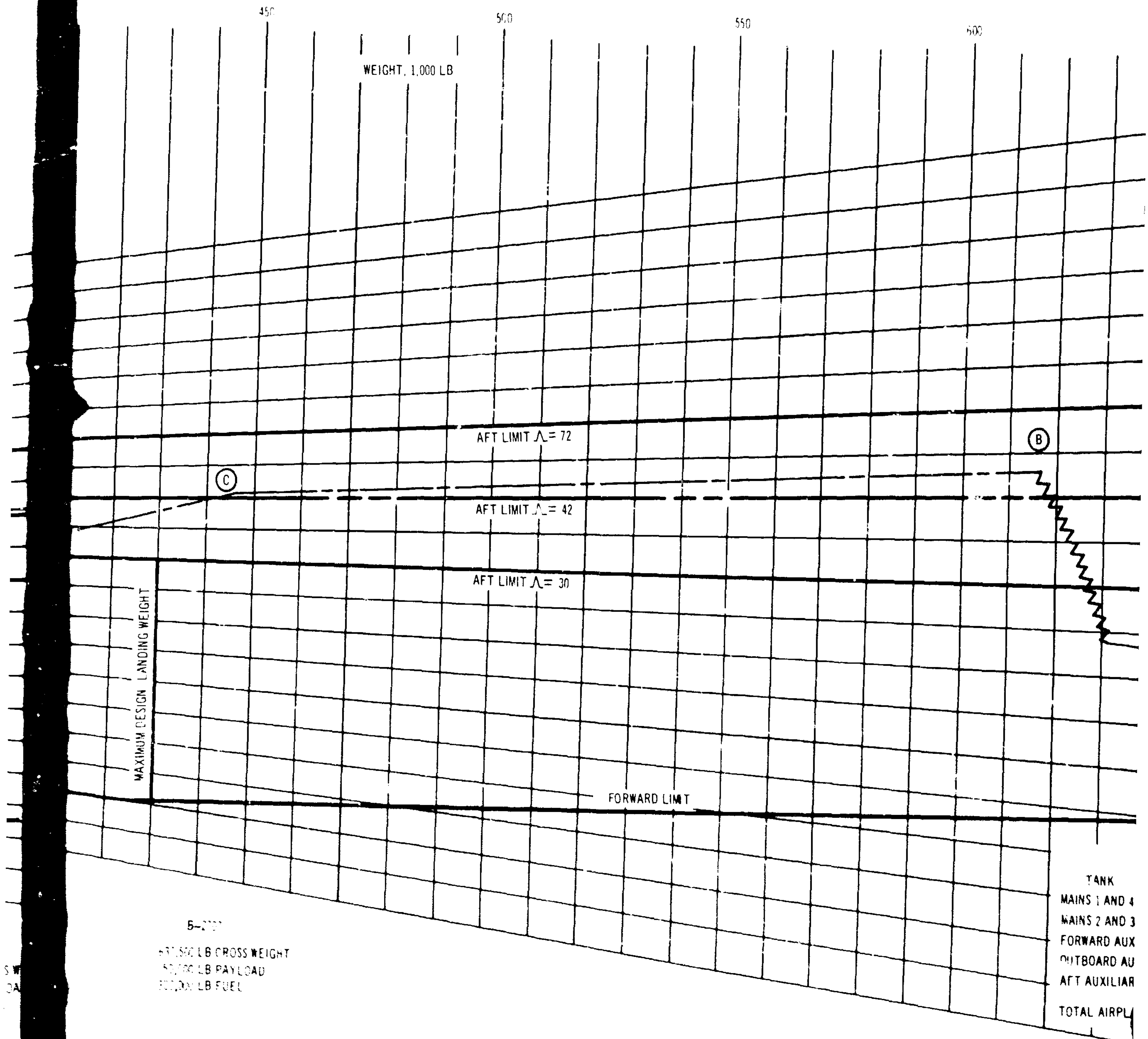


Figure 2-39. Center of Gravity Management (P&WA)

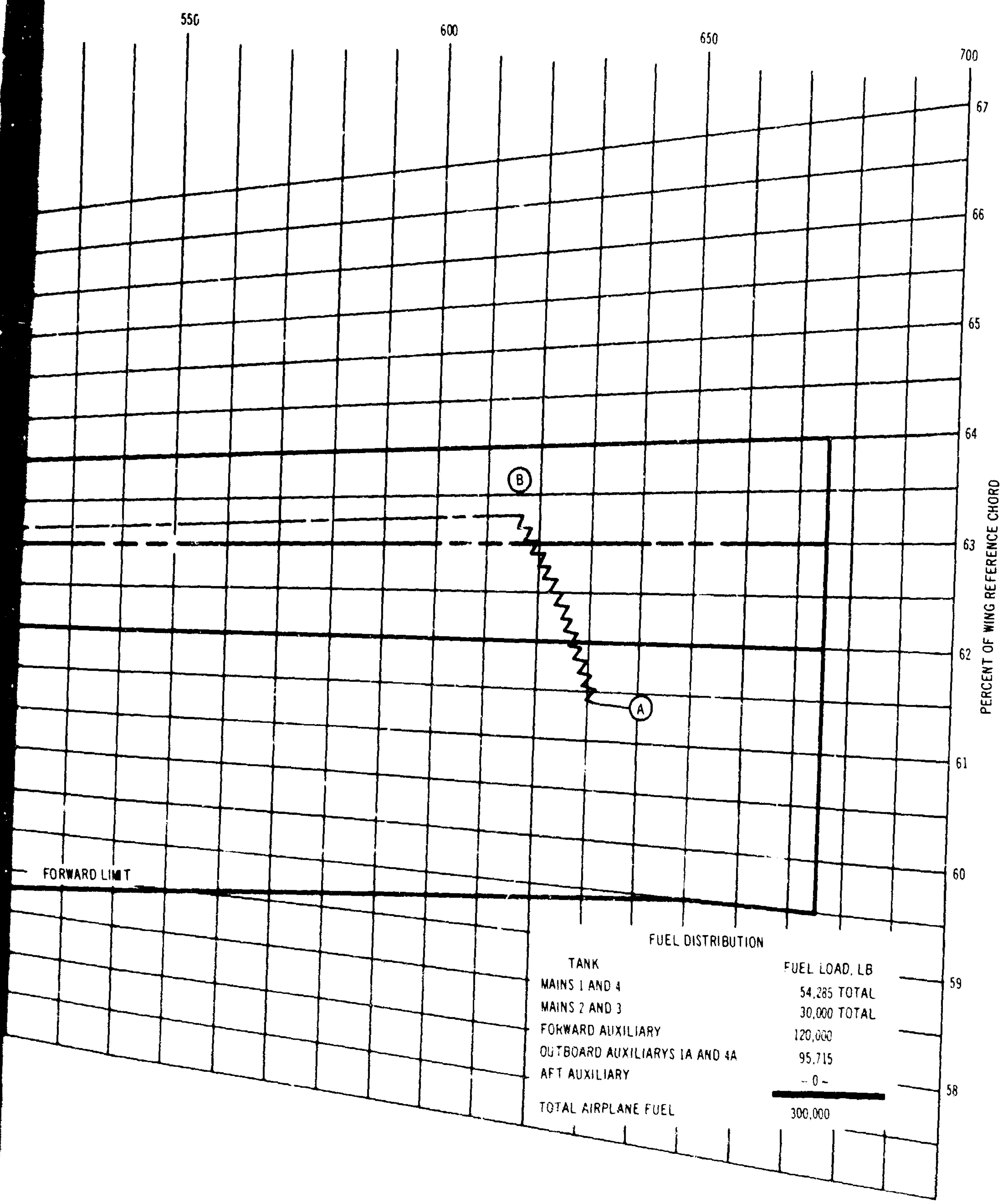


Figure 2–39. Center of Gravity Management (P&WA)

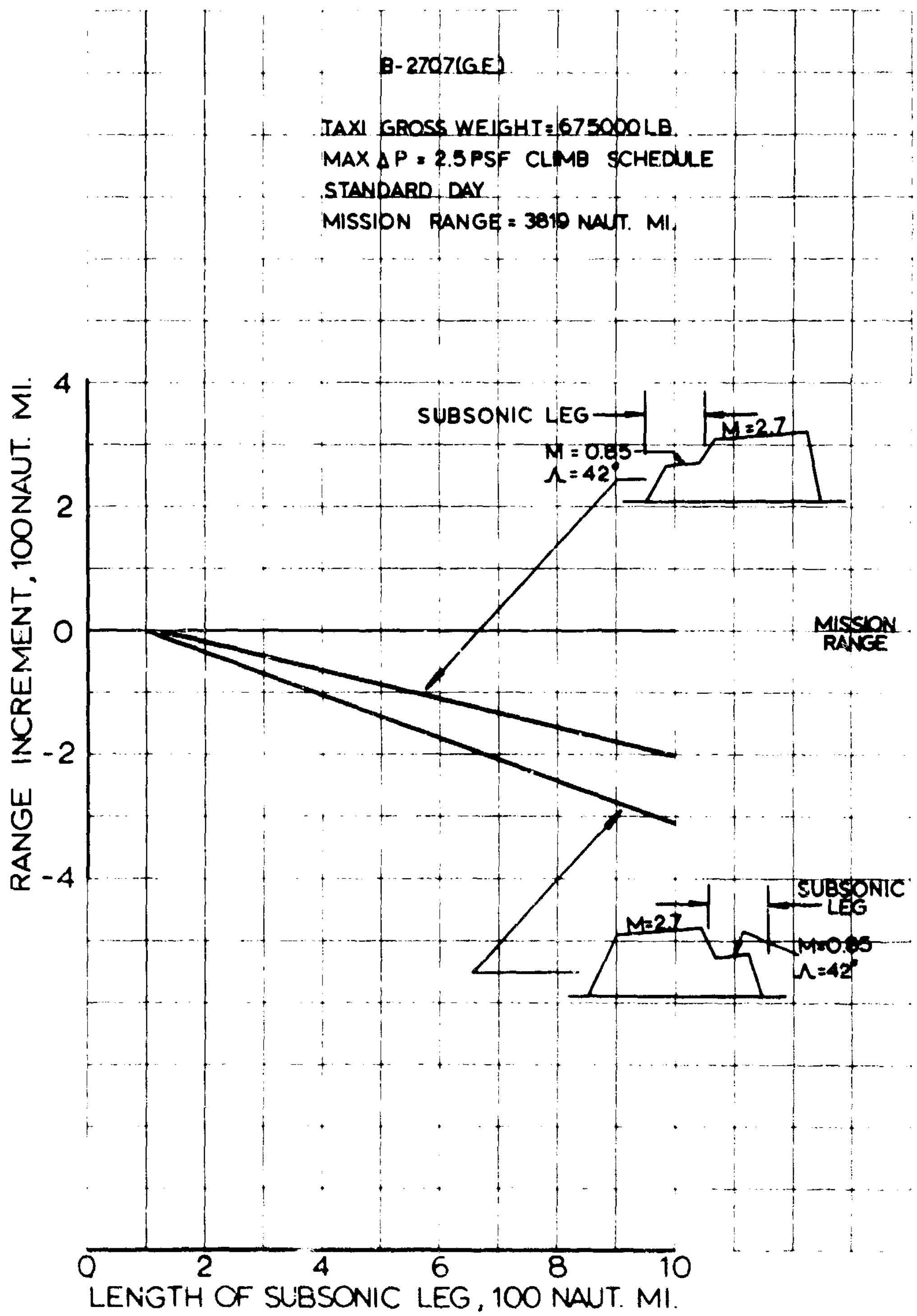


Figure 2–40. B–2707 (GE) Split Mission Summary

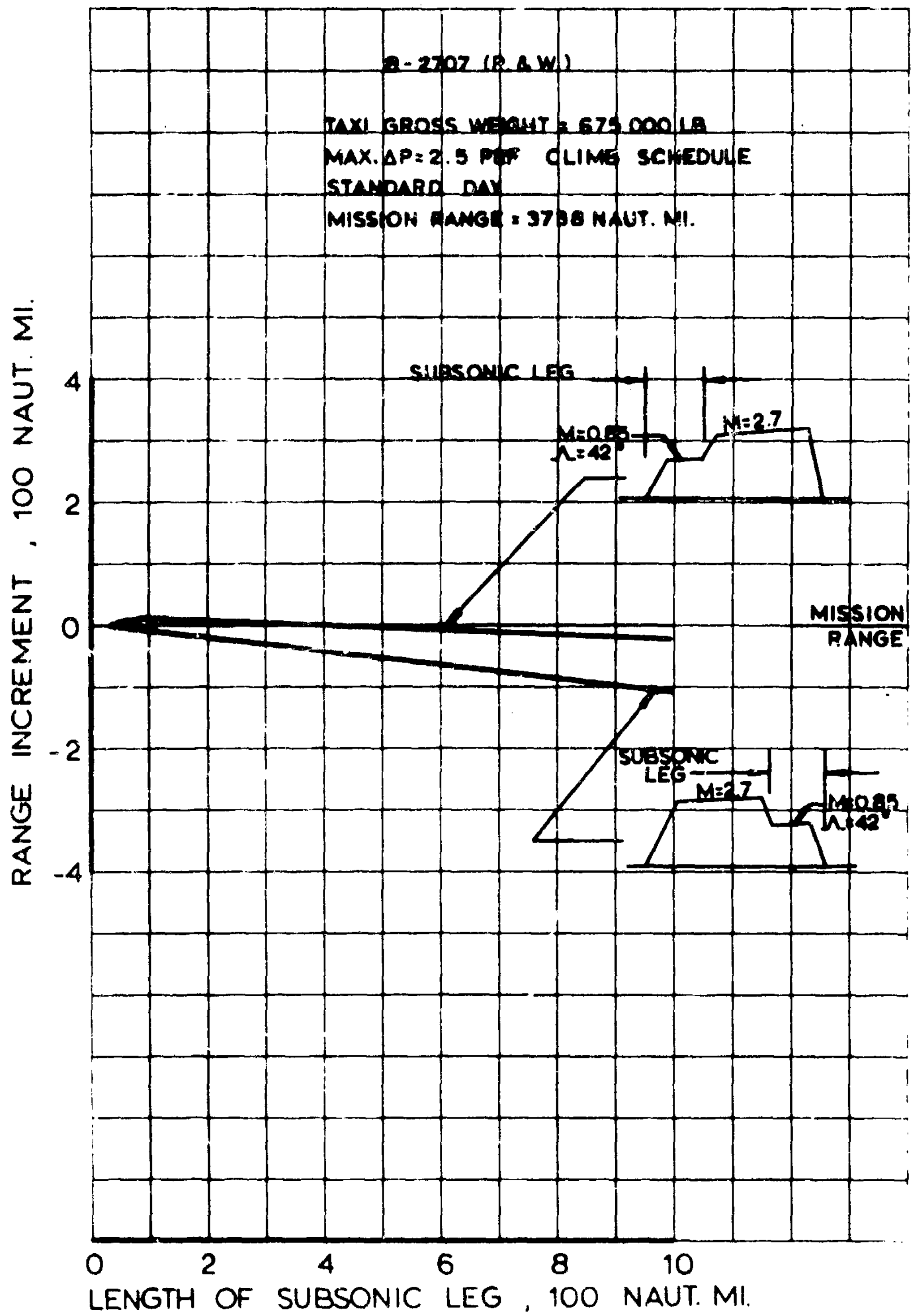


Figure 2-41. B-2707 (P&WA) Split Mission Summary

The effect of propulsion failure on total range is shown in Figs. 2-42 and 2-43. In the event of a propulsion failure, the pilot has the option of continuing supersonically or subsonically at a lower altitude. The plots show that the reserve fuel available on arrival at the original destination (3,819 nmi) is always in excess of that required for a 15-minute hold at the destination.

2.6.4.2 Cabin Pressurization Failure

Blowout of a single passenger window (33.2 sq in.) will not be catastrophic. As soon as the cabin altitude rate-of-change sensor senses the pressure drop, the boost compressors are switched to the high flow mode and the cabin altitude warning horn sounds. With three of four available compressors operating, the cabin pressure altitude will not exceed 7,000 ft, assuming that the pilot begins emergency descent within 17 seconds (per current FAR) of the sounding of the cabin altitude warning horn. During the descent, cabin pressure altitude will stabilize between 6,000 and 7,000 ft. Similarly, a structural blowout (42 sq in.) which is the maximum tear stopper design with only three air sources operating will cause cabin pressure altitude to reach a maximum of 13,000 ft (Figs. 2-44 and 2-45).

In the event that all engines lose thrust, the cabin altitude is held to a maximum of 14,000 ft. This is accomplished by operating one boost compressor from the engine windmilling drive power (Fig. 2-46). See Par. 2.9 for further discussion of abnormal conditions.

2.6.4.3 Loss of Hydraulic System

Loss of one hydraulic power system does not require any unusual action by the flight crew. Loss of two hydraulic power systems will necessitate the reduction from supersonic to subsonic cruise speeds. Subsonic cruise can be maintained with the remaining system although maneuverability rates are reduced and wing speed actuation is slowed to 30 percent of normal operating speed. A standby hydraulic power system provides a backup for landing gear extension and brakes.

With all four engines inoperative, the flight controls are operated by hydraulic power generated through the ADS by engine windmilling power (P&WA engine) or by hydraulic power generated through the ram air turbine (GE engine). (See Par. 2.9.8.)

2.6.5 Handling Characteristics

The turn radius associated with supersonic speeds is much larger than at subsonic speeds. In a 30-deg bank angle at 1,550 knots TAS, the B-2707 turns with a 60 nmi radius compared to 9 nmi for a 600-knot jet (Fig. 2-47).

An important consideration of high Mach cruise is the ability of the pilot to hold desired altitude. One measure of this capability is the parameter $N_{z\alpha}$ which is the vertical acceleration of the airplane for small changes in angle of attack. Airplanes with large values of $N_{z\alpha}$ are sensitive and tend to be difficult to control with regard to rate of climb or altitude. Lower values produce easily managed pitch response and are desirable, especially in conditions of low damping. Extremely low values are undesirable since they produce sluggish response. Rigid airplanes tend to have increasing values of $N_{z\alpha}$ with increasing dynamic pressure. Conventional airplanes with relatively rigid structure that are capable of flying through large ratios of maximum speed to minimum speed tend to have undesirable low values at low speed and over sensitive high values at high speed. Because of the variable-wing sweep feature, the B-2707 is able to maintain an approximately constant near ideal level of $N_{z\alpha}$. The values of $N_{z\alpha}$ throughout most of the flight profile vary between 0.1 and 0.3 g's per deg, which is very similar to present-day transports at medium operating speeds. However, at the higher true airspeed, the flightpath angle change, and subsequently the airplane's attitude change, is quite small for a given change in angle of attack.

The effect of higher speed on controllability is appreciated when one realizes that when a small attitude change occurs slowly without the pilot's knowledge, the rate of climb or descent can become quite high and the altitude excursion quite large, even though the attitude change is small.

Consequently, the ability of the pilot to hold altitude is also intimately related to the quality and resolution of his air data and attitude indicator. For this reason, improved pitch and roll attitude resolution is provided along with visual indicators with a digital readout on air data information so that accurate speed and altitude information, as well as rate of change of speed and altitude is easily perceived.

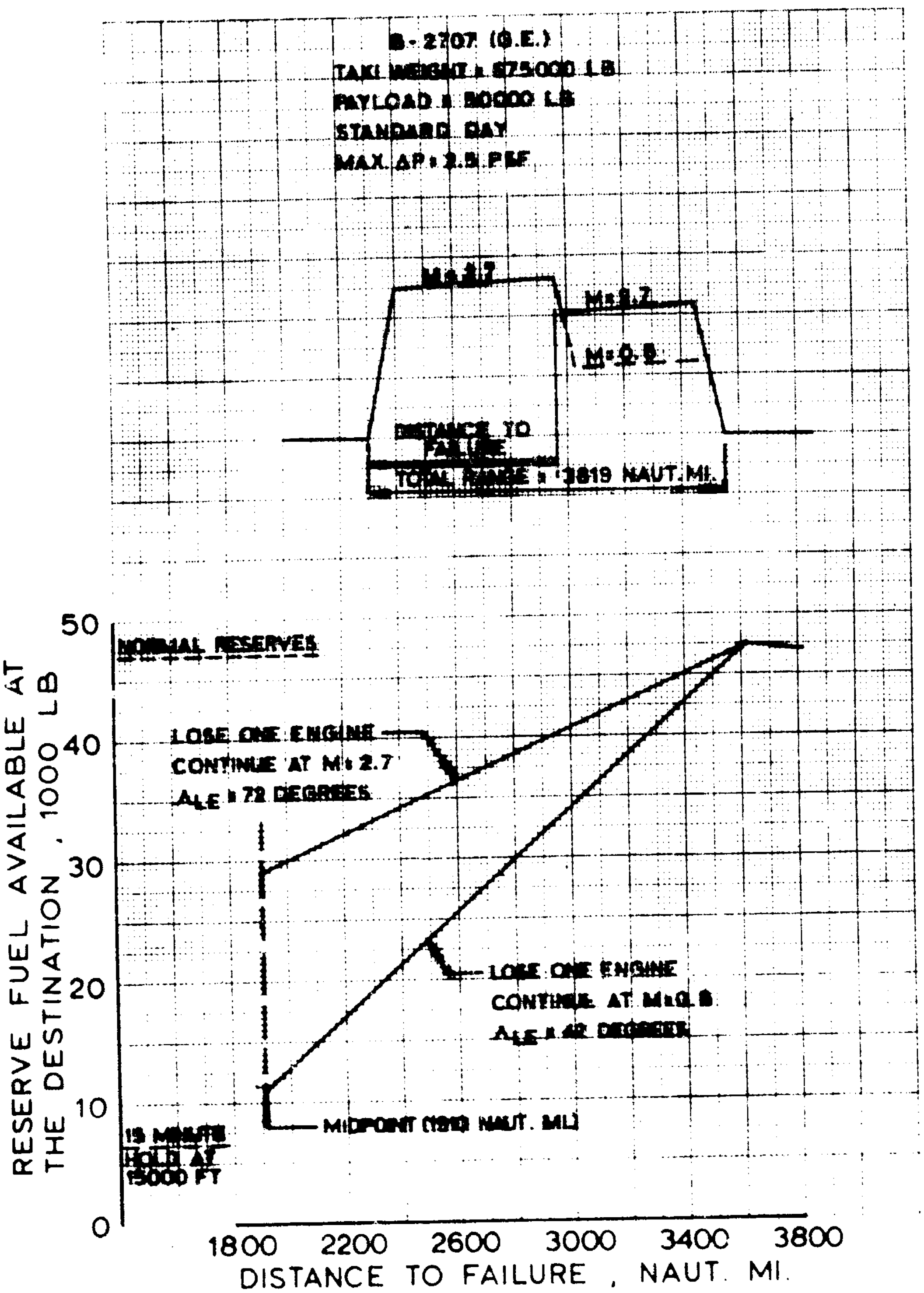


Figure 2-42. B-2707 (GE) Mid-Point Propulsion Failure

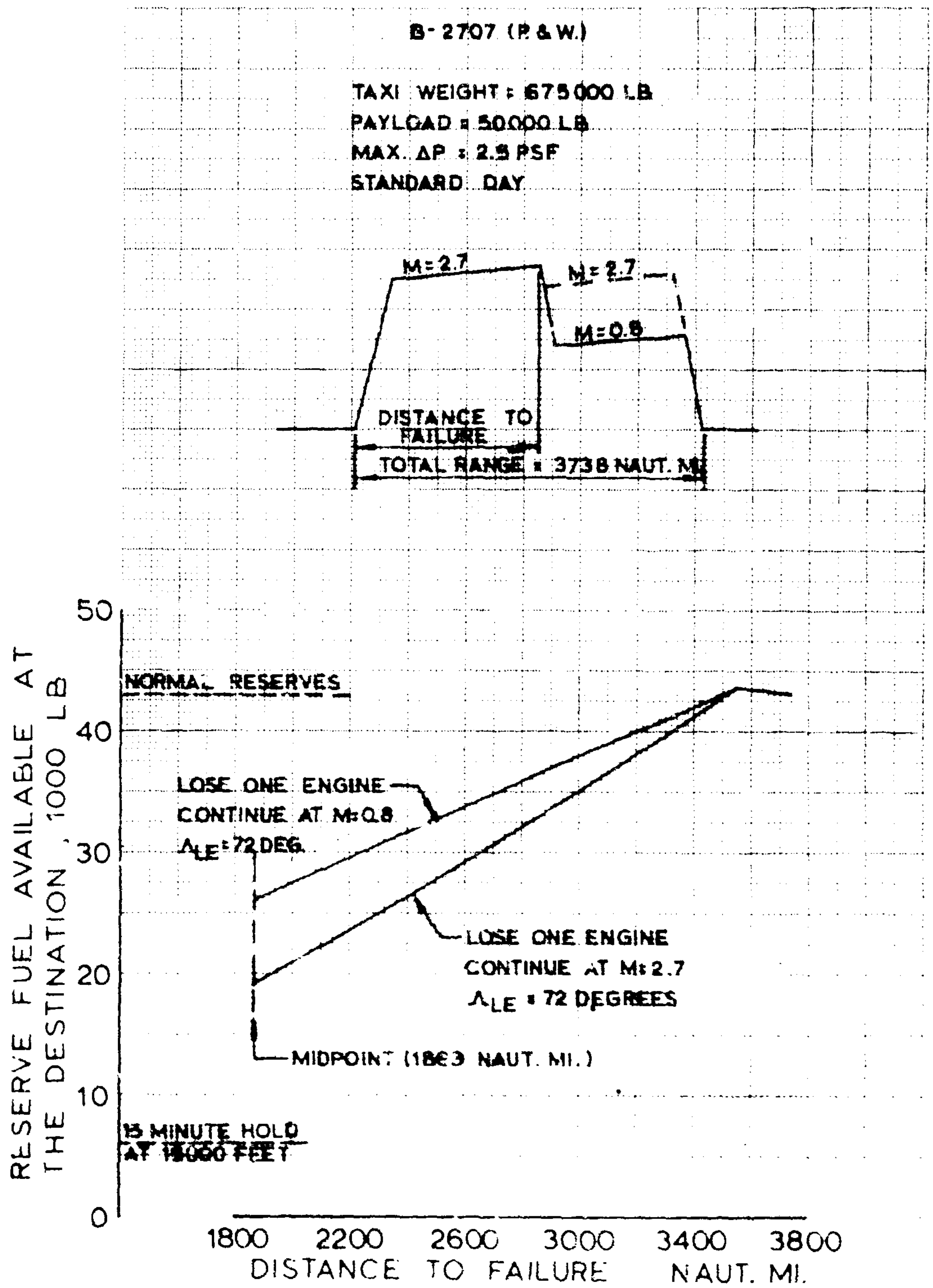


Figure 2–43. B–2707 (P&WA) Mid-Point Propulsion Failure

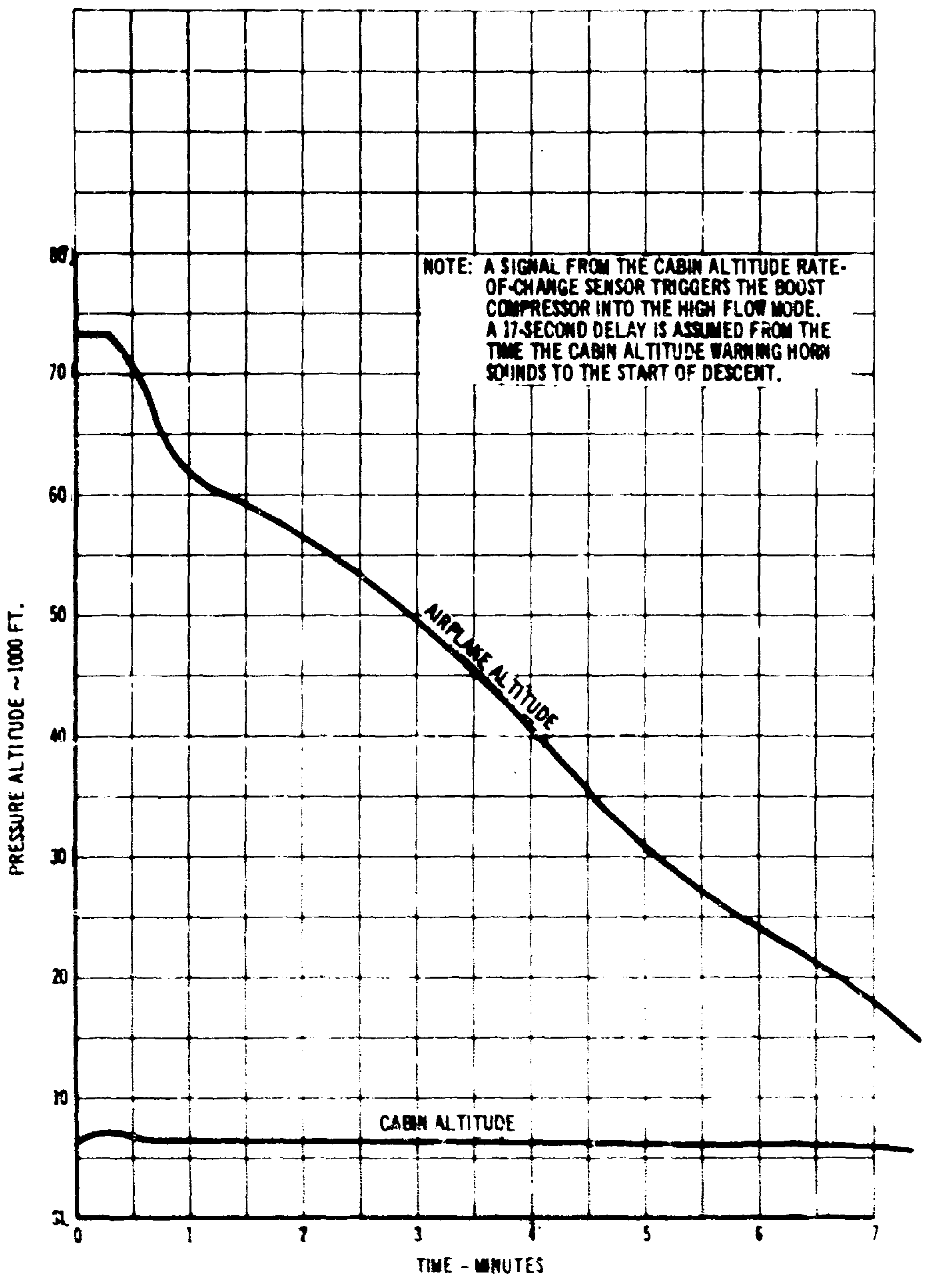


Figure 2–44. Cabin Altitude Transient Following the Blowout of a Passenger Window of 33.2 Sq In. With High Mode Inflow From Three Air Sources

V4-B2707-1

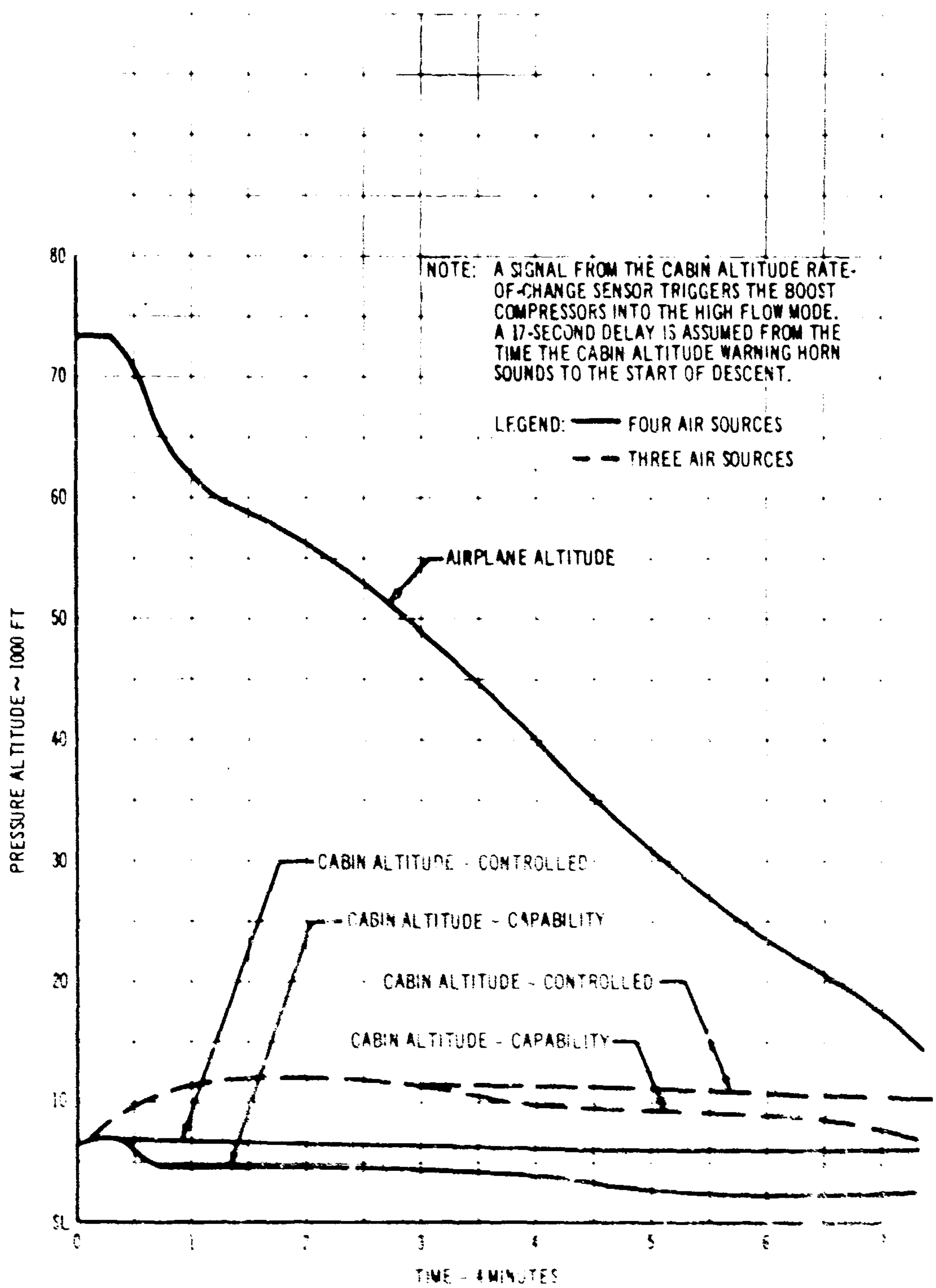


Figure 2–45. Cabin Altitude Transient Following a Structural Blowout of 4 Sq In. With High Mode Inflow From Three and Four Air Sources

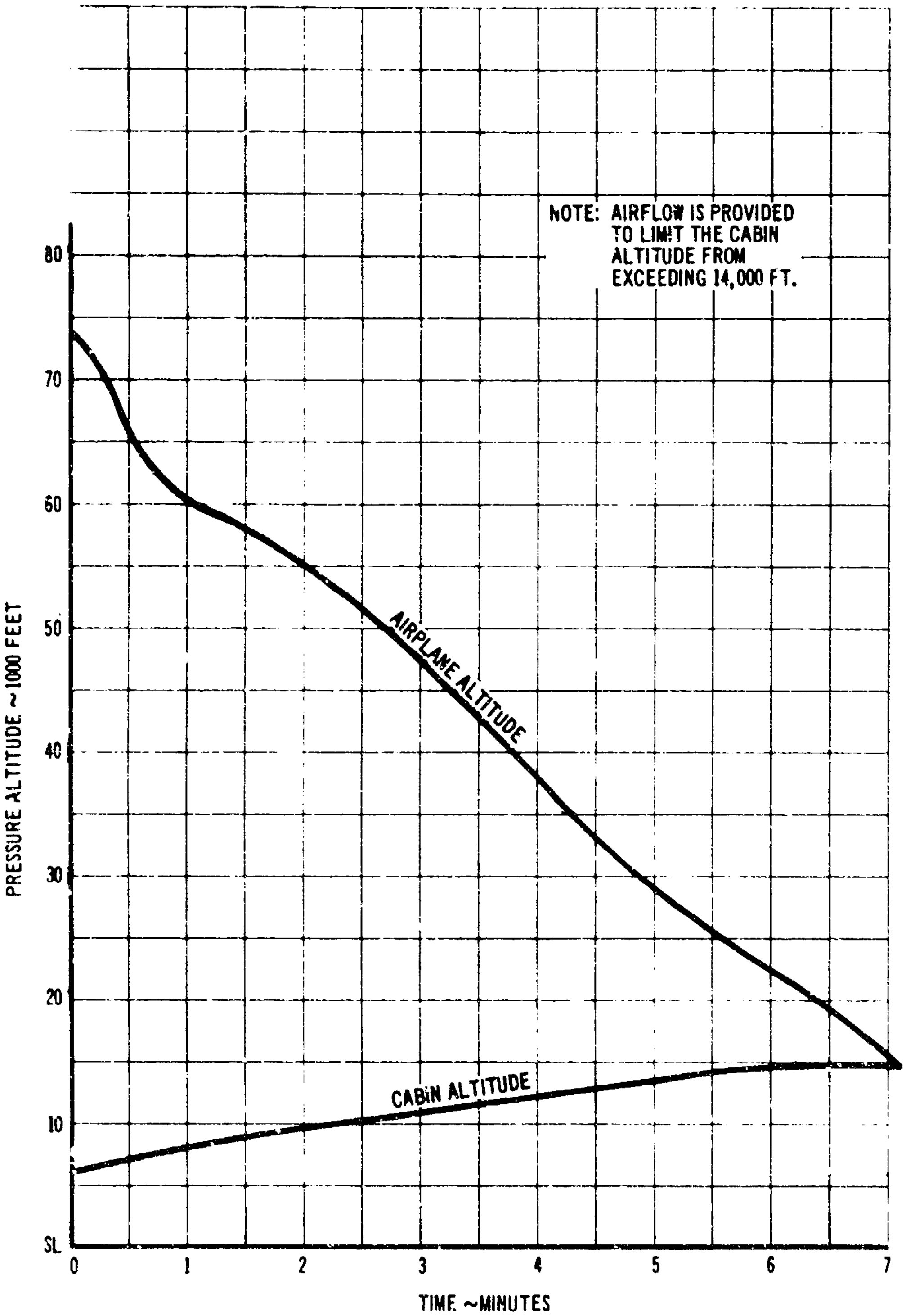


Figure 2–46. Cabin Altitude Transient Following Failure of All Engines

V4-B2707-1

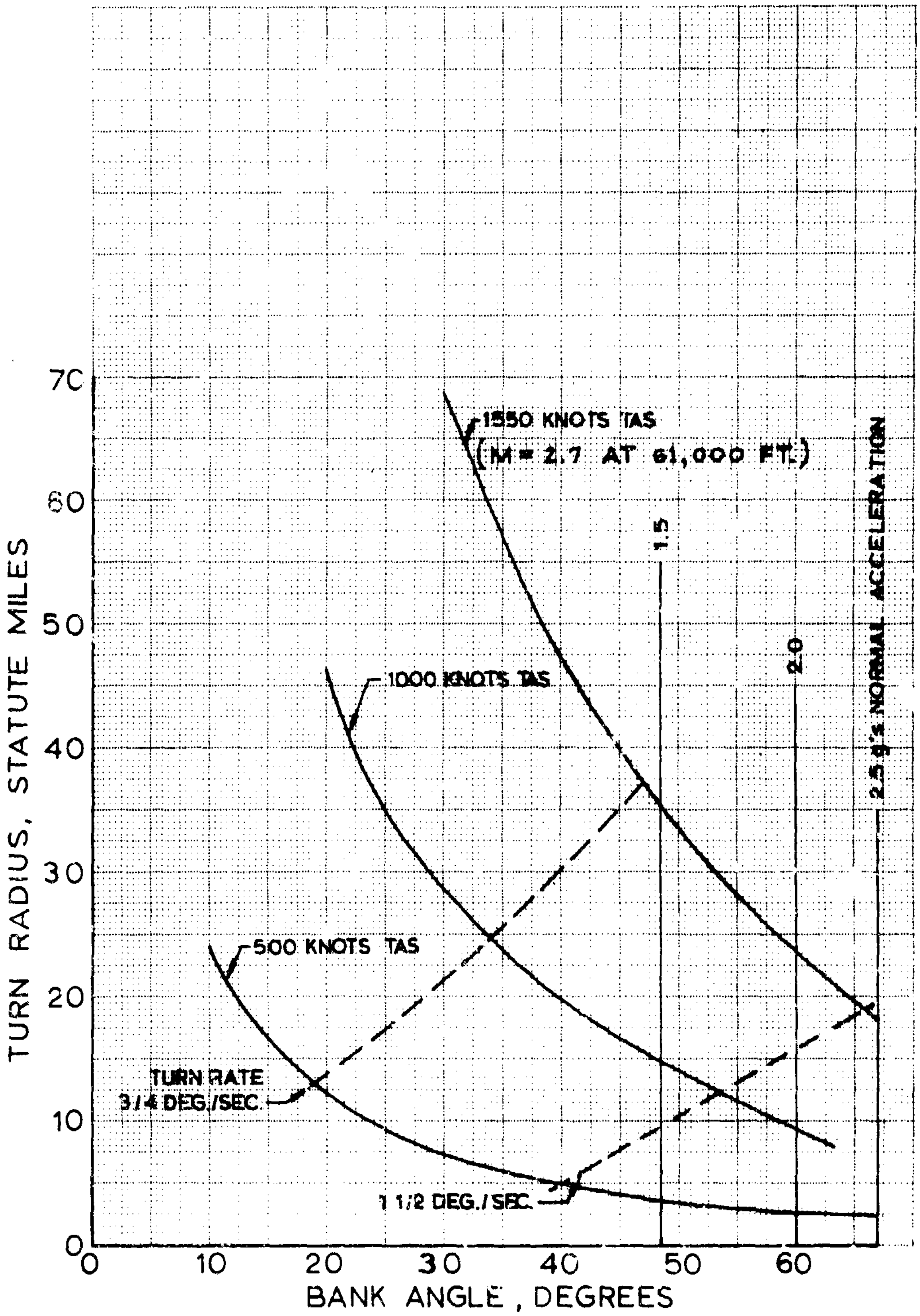


Figure 2–47. Turn Radius

V4-B2707-1

The map display and the Mach-altitude display present essential information continuously to the pilot in a pictorial, integrated, and easily understood form.

The normal handling of the airplane during cruise presents no problem given the improved instrumentation. SAS off characteristics require a little more pilot attention due to the low damping about all axes and some lateral-directional coupling.

2.7 DECELERATION AND DESCENT

2.7.1 Normal Descent Procedure and Performance

The normal deceleration and descent schedule (Fig. 2-48) has been planned with the following primary considerations:

- Operational simplicity and safety
- Overall mission range and block time
- Minimum practical sonic boom
- 300 fpm (maximum cabin rate of descent)

The B-2707 can slow down at any time without fuel transfer or cg manipulation. The cabin altitude at the end of cruise is approximately 6,100 ft. The airplane starts to descend at a constant calibrated airspeed, essentially the same airspeed held at the end of cruise (480 knots CAS for normal mission) (Fig. 2-48). The 72-deg wing sweep is maintained until the airplane decelerates to subsonic speed. The maximum sonic boom overpressure generated in a normal descent is 1.6psf. The descent is flown using the same aids as were used for the climb. The airplane becomes subsonic at 44,500 ft. The airplane descends subsonically in a manner similar to current jet transports. The wing is normally started forward at Mach 0.9 or less to end up at 42 deg. The wing sweep schedule is shown in Fig. 2-48. The descent times and distances are shown in Fig. 2-49. The descent profile will change very little with variations in gross weight.

A rapid descent can reduce the block time by 5 minutes, but it can also reduce the overall range by approximately 31 miles. The airplane would go subsonic within 48 miles of the terminal area, compared to 80 miles out for the normal descent. The rapid descent is flown using the normal descent schedule, but with earlier deployment of spoilers and landing gear.

2.7.2 Holding

From an economy standpoint, the flight should descend to subsonic conditions once the descent has been started. Holding, if required, should be planned for subsonic speeds at lower altitudes. Holding would be accomplished at altitudes of approximately 15 to 30,000 ft, 280 knots CAS, and a 30 deg wing-sweep angle.

2.7.3 Emergency Descent Procedure and Performance

The emergency descent is based on the following considerations:

- Blowout area limited to 42 sq in. by tear stopper design (window area 33.2 sq in.)
- 17-second delay for crew mask donning and passenger seat belt security
- M_{MO}/V_{MO} flight profile with maximum longitudinal deceleration limited to 0.5 g
- Aircraft level-off altitude 14,000 ft
- Spoilers extended full up throughout the descent and the landing gear is extended at its subsonic placard.

The M_{MO}/V_{MO} profile (Fig. 2-48) is flown using the barber-pole pointer on the airspeed indicators very similar to current practice. Additional aid is provided by the Mach-altitude situation display. If a M_{MO}/V_{MO} emergency descent is initiated at the top of the final climb (570,000 lb), a maximum descent overpressure of 3.22 psf results. The maximum rates of descent and body attitudes occur at lighter weights as shown below:

	Max Rate Descent (fpm)	Max Body Attitude (deg)
End of climb gross weight 570,000 lb	6,000	-1.5
End of cruise 400,000 lb	12,000	-5

The body attitudes are mild compared to current subsonic transports which nose down nearly 20 deg in an emergency descent. Figure 2-45 shows the cabin altitude profile during an emergency descent.

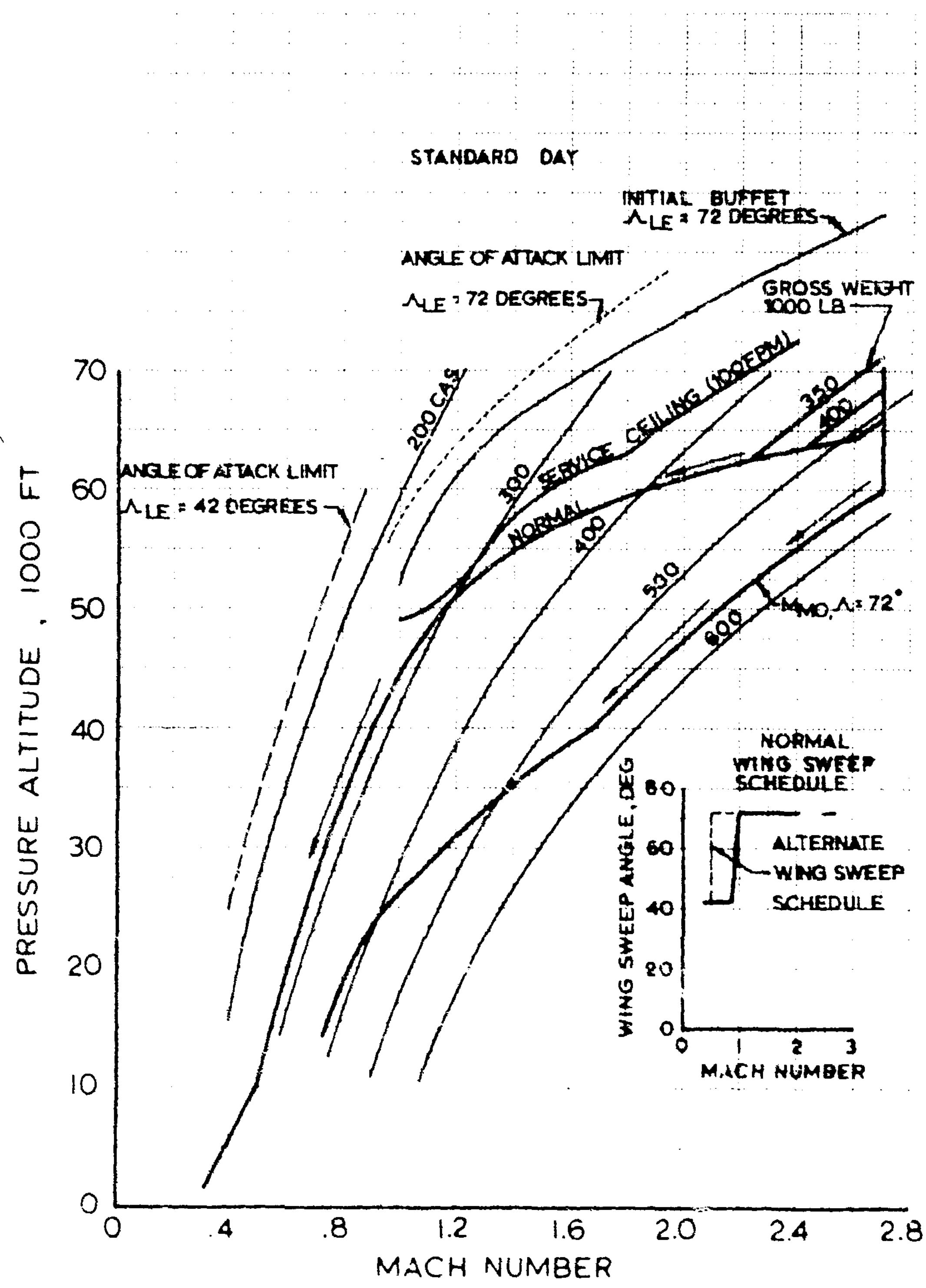


Figure 2–48. Descent Schedules

V4-B2707-1

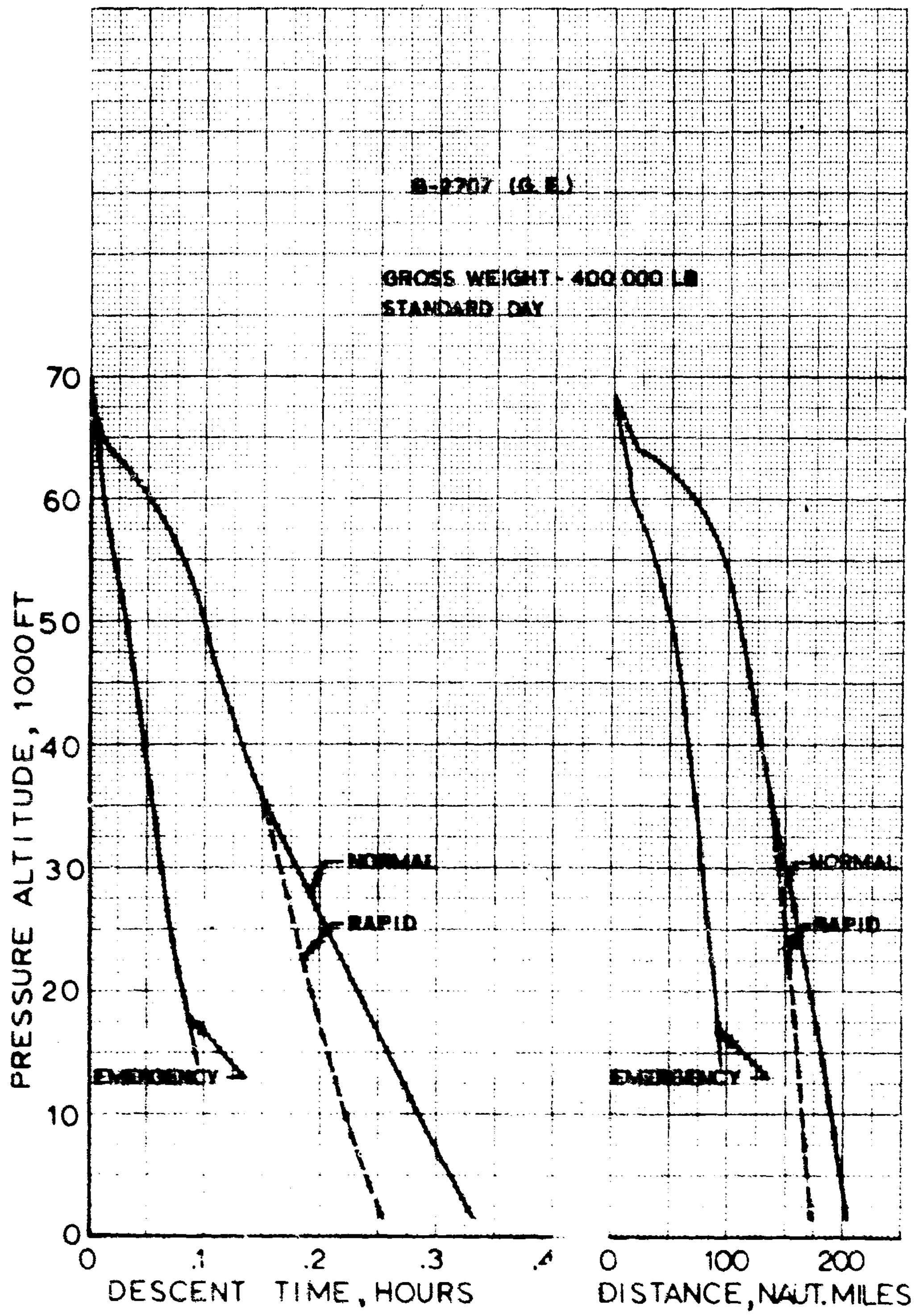


Figure 2-49. Descent Profiles

2.7.4 Performance Margins
The initial buffet speed margins in the descent are excellent and provide a high level of safety (Fig. 2-48). The airplane has a minimum maneuvering capability of 0.5 g before initial buffet during descent.

The normal mission descent schedule is shown at least 1,500 ft below the service ceiling so that the airplane can level off and hold speed at any time should traffic or weather conditions require.

2.8 APPROACH AND LANDING PROCEDURE

The B-2707 has excellent landing characteristics. Landing speeds and field lengths are similar to those for subsonic jets. The flight deck attitude on approach is approximately one degree. This is less than the 707 and results in excellent forward vision. The reverse thrust system effectively reverses 50 percent of the forward thrust or approximately 26,000 lb per engine. The high level of reverse thrust from the large engines yield a very comfortable safety margin for landings on wet or icy runways. The high lift-to-drag ratio in the approach configuration permits low approach thrust settings, which result in very low noise levels. The relationship of thrust and drag is stable on approach so that it is easy to hold approach speeds and glide angles (Figs. 2-50 and 2-51).

2.8.1 Normal Approach and Landing Procedure
The wings are swept forward to 42 deg during descent and to 30 deg prior to approach. Flaps are extended with the wings at 30 deg prior to final approach where full flaps and gear are extended. Inflight spoilers and landing gear which can be extended (270 knots) and retracted (250 knots) give the pilot the ability to slow down, hold, and regulate speed and descent rate as desired by the traffic controller (Table 2-D).

2.8.1.1 Approach Speeds and Margins
The normal approach speed for full flaps is 1.3 times stall-speed. It is well above the speed for minimum thrust; the speed can thus be held very easily with a minimum of thrust lever manipulations.

Figures 2-50 and 2-51 show the thrust required and thrust available versus speed on approach. The approach speed is on the stable side of the thrust required curve.

Table 2-D shows the descent capability with idle thrust for making large corrections in flight path angle prior to or during approach. This provides considerable operational flexibility and illustrates the airplane's capability for fitting into terminal area traffic patterns.

Another factor that is important to the pilot, particularly during approach and landing, is the engine acceleration characteristics. Figures 2-52 and 2-53 show an engine acceleration time of 4.5 seconds from idle to 95 percent maximum dry thrust. Time from approach thrust to 95 percent maximum dry thrust is only 2.5 seconds.

A comparison of the B-2707 and the 707-320 approach performance for various thrust settings is shown in Figs. 2-54 and 2-55.

2.8.1.2 Landing Field Lengths
The landing distances are comparable to present day jets (Fig. 2-56). The excellent reverser effectiveness and the rapid engine acceleration characteristics provide distances comparable to dry runway (brakes only) landing distances for very wet or icy runway conditions. At maximum landing gross weight with 3 engines, the wet runway FAR field length is 7,000 ft.

The normal landing weight at the end of the intercontinental mission is 384,000 lb. At this weight the approach speed for flaps to 30/50 deg (standard day, sea level), is 136 knots CAS and the FAR field length is 6,280 ft (no reverse thrust) (Fig. 2-56). A Boeing 707-320-series airplane at maximum landing weight would approach at 137 knots CAS, and has a FAR field length of 6,060 ft. The actual landing distance required to clear a 50-ft obstacle at a landing weight of 384,000 lb, utilizing 4 engines in reverse thrust, is 3,300 ft. A summary of landing performance for dry and wet runways is shown in Fig. 2-57.

2.8.1.3 Community Noise Levels
On current subsonic jets the major source of noise is the compressor whine. On the B-2707 inlet airflow, choking is used to achieve compressor noise suppression. During the approach, compressor noise is eliminated as a contributor to the total noise (Ref. Airport and Community Noise Program, V4-B2707-4). Figures 2-58 and 2-60 show the resulting noise levels and contours

experienced in the community, 1 mile before threshold, using a flap setting of 20/40 deg and a constant approach speed.

A further reduction in noise will result if the following approach is used: flaps 20/40 deg down to approximately 500 ft height at normal approach speed plus a given speed increment, reduce thrust and start extending flaps to 30/50 deg, then increase thrust at an altitude of 300 ft after decelerating to normal approach speed. Trim changes are quite small due to the small thrust and speed change required. The attitude during approach is the same as that for a normal approach. On an ILS approach this procedure may be accomplished using the autopilot and auto-throttles; however, it can also be handled by the pilot using the flight director and auto-throttles.

For a VFR approach, the procedure is feasible using manual throttles, because the airspeed rate information will assist in resetting approach thrust. Community noise profiles and contours for the decelerating approach are shown in Figs. 2-59 and 2-61.

The versatility of the B-2707 during approach is illustrated in the noise trade plots, Figs. 2-62 and 2-63.

2.8.2 All-Weather Landing Capability and Procedure

2.8.2.1 Introduction

The B-2707 will be certified for landing in weather minimums of 700 ft runway visual range (RVR). To achieve this goal a fail operational automatic flight control system, with the capability of controlling the airplane to touchdown, is installed. A fail passive auto-throttle system is installed to control the airspeed on the glide slope and to reduce thrust for landing.

The fail operational flight control system can sustain one failure and continue to operate without a degradation in performance. A second failure will result in a disconnect without disturbing the flight path of the airplane.

The thrust control does not demand the same degree of attention as the flight controls. Therefore, the automatic throttle system is a dual system designed so that a failure will cause a disconnect and warn the pilot without disturbing the thrust setting.

2.8.2.2 Operation

The automatic flight control system includes a mode selector panel mounted below the center glare shield and a steering control panel on the center aisle stand. The steering control panel gives the pilot his choice of heading select or bank angle control and vertical velocity control. The auto-throttle controls are adjacent to the mode selector.

The operation of the automatic flight control system can be monitored by observing the approach progress display above the ADI. This display indicates the mode of operation on lights which turn amber when the system is armed, and green when the system engages. The modes displayed are localizer, glide slope, flare and go-around.

Instrumentation for monitoring the performance of the system is displayed on the ADI. Raw data localizer, glide slope, altitude and speed from the selected values are displayed on this indicator, in addition to flight director commands and roll and pitch attitude. Vertical velocity is displayed on an adjacent instrument. Combining data on the ADI and grouping instruments provides the pilot with a complete situation and velocity display within his cone of vision.

Pilot procedure for operating the all-weather landing system is similar to the procedure for operating the systems presently certified on the 707 and 727 airplanes.

Maneuvering, in response to ground radar instructions can be accomplished with either the turn controller or the heading select control. The auto-throttle system will maintain the desired airspeed. The radio control panels for frequency selection are located adjacent to the autopilot mode selector panel. This selector also supplies information for the ADI. The course selectors for selecting ILS courses are located on the autopilot mode selector panel so that the complete approach situation can be made with one position of the hand.

Table 2-D. Descent Rates

B-2707 (GE)
Gross Weight at Beginning of Descent = 400,000 lb
Thrust = Idle
Standard Day

Wing Sweep Angle, Degrees	Flaps Degrees	Landing Gear	Spoilers	V_c, kn	Altitude, ft	Rate of Descent, fpm
42	0/0	Up	Down	240	4000	1,670
42	0/0	Down	Up	240	4000	6,090
30	5/5	Up	Down	240	4000	2,480
30	5/5	Up	Up	240	4000	6,075
30	20/40	Down	Down	180	Sea level	4,095
30	20/40	Down	Up	180	Sea level	6,080
30	30/50	Down	Down	180	Sea level	5,480
30	30/50	Down	Up	180	Sea level	7,465
30	30/50	Down	Down	135	Sea level	2,755
30	30/50	Down	Up	135	Sea level	3,610

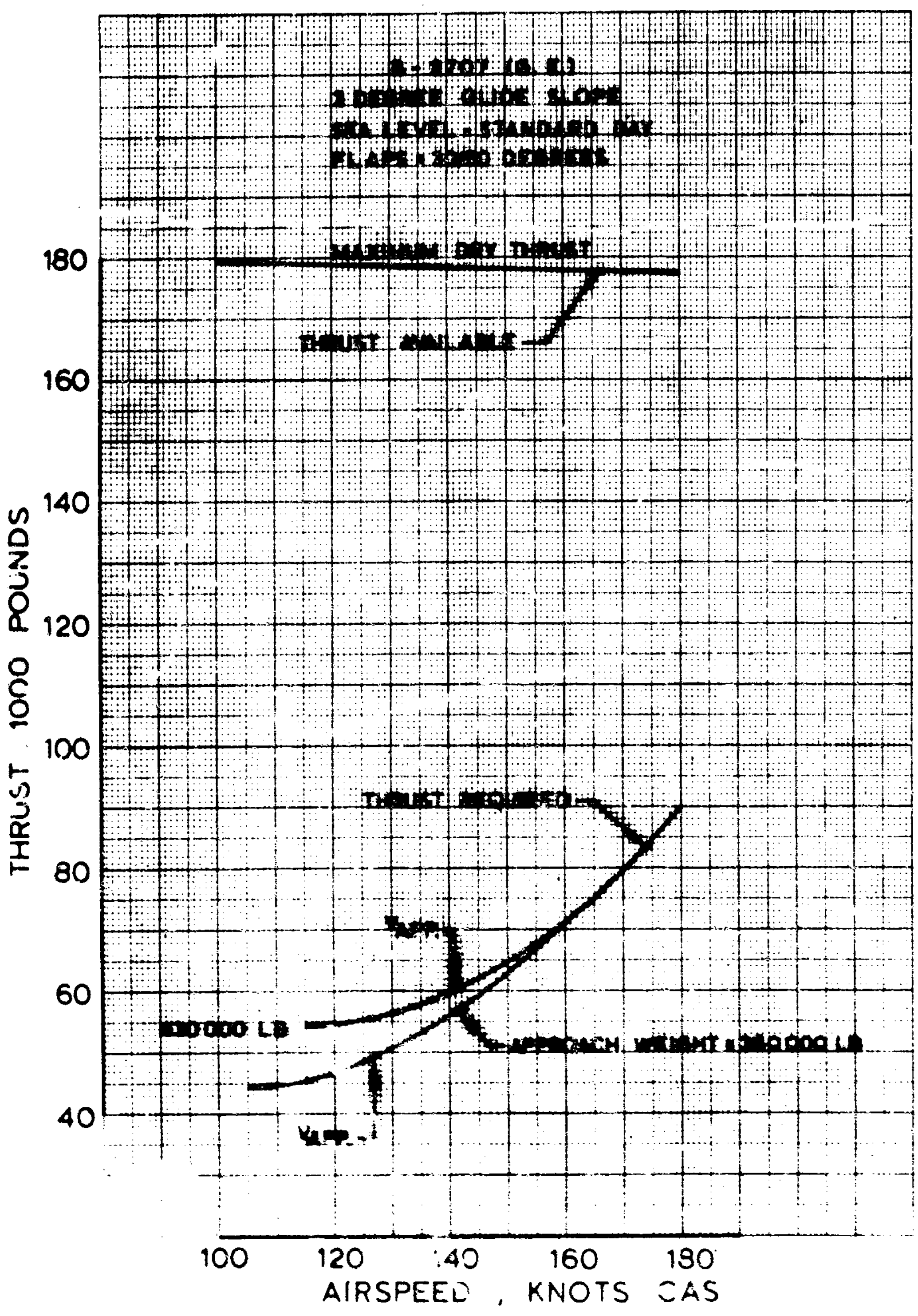


Figure 2-50. B-2707 (GE) Thrust-Speed Stability

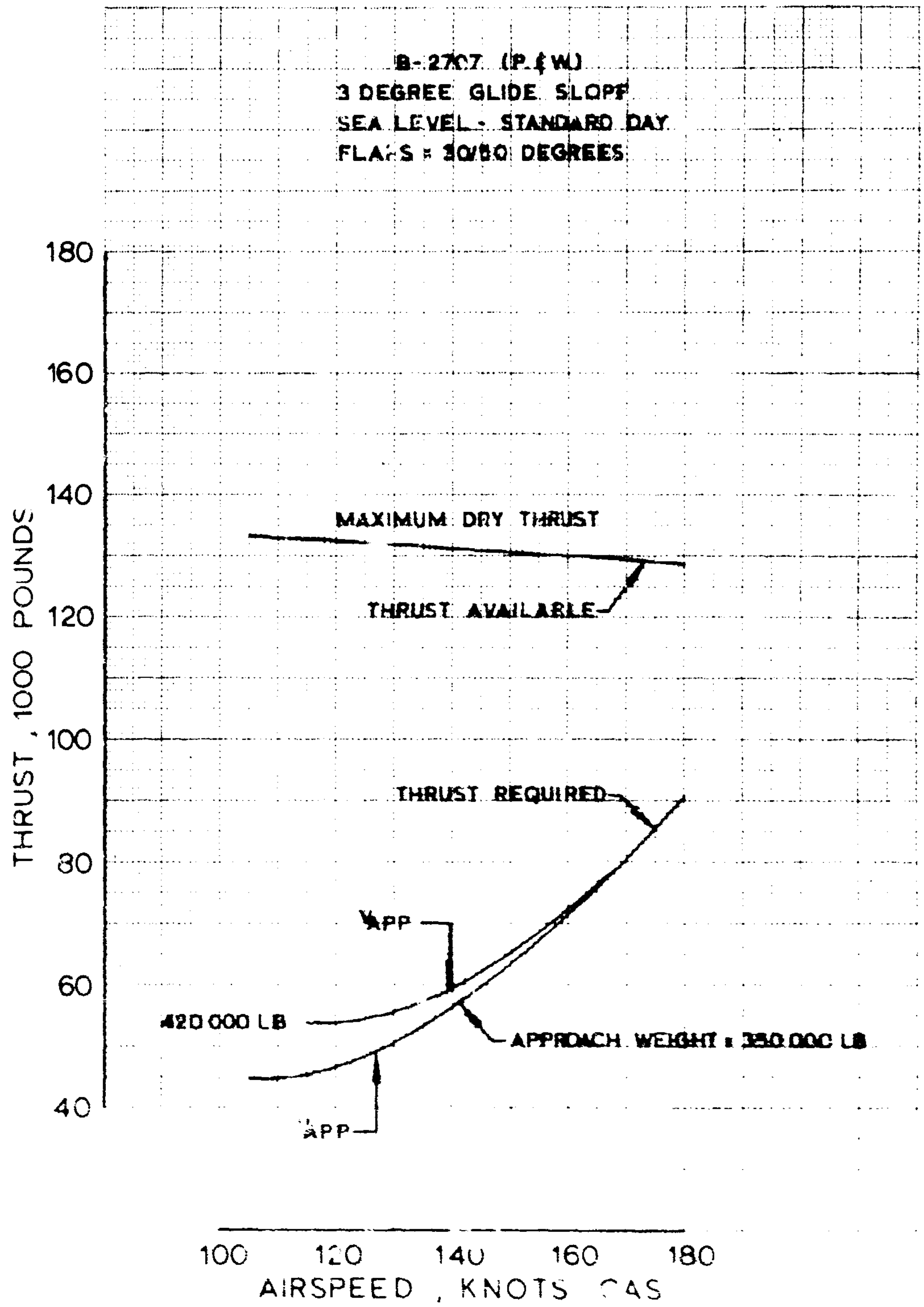


Figure 2-51. B-2707 (P&WA) Thrust-Speed Stability

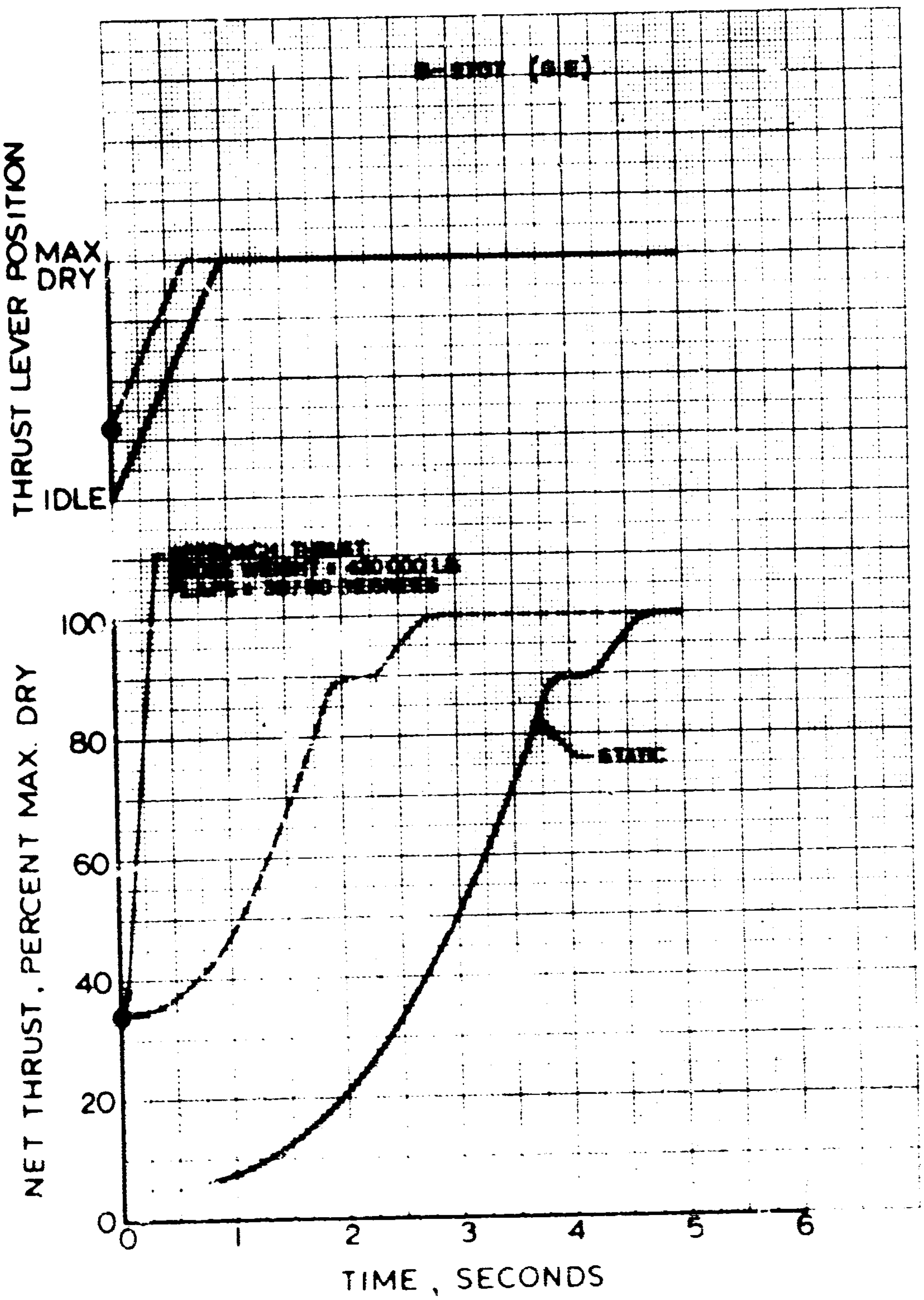


Figure 2-52. B-2707 (GE) Engine Acceleration

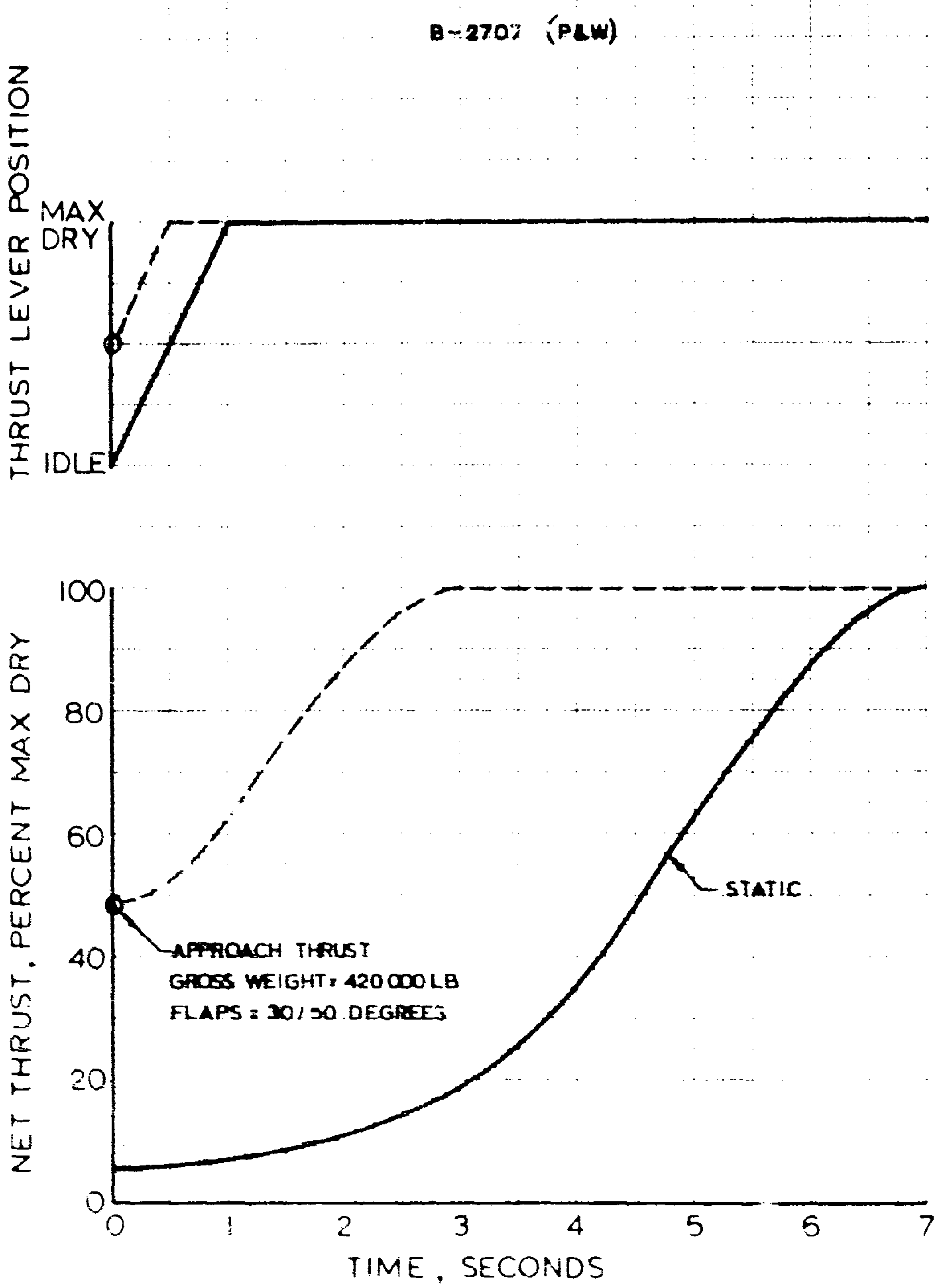


Figure 2-53. B-2707 (P&WA) Engine Acceleration

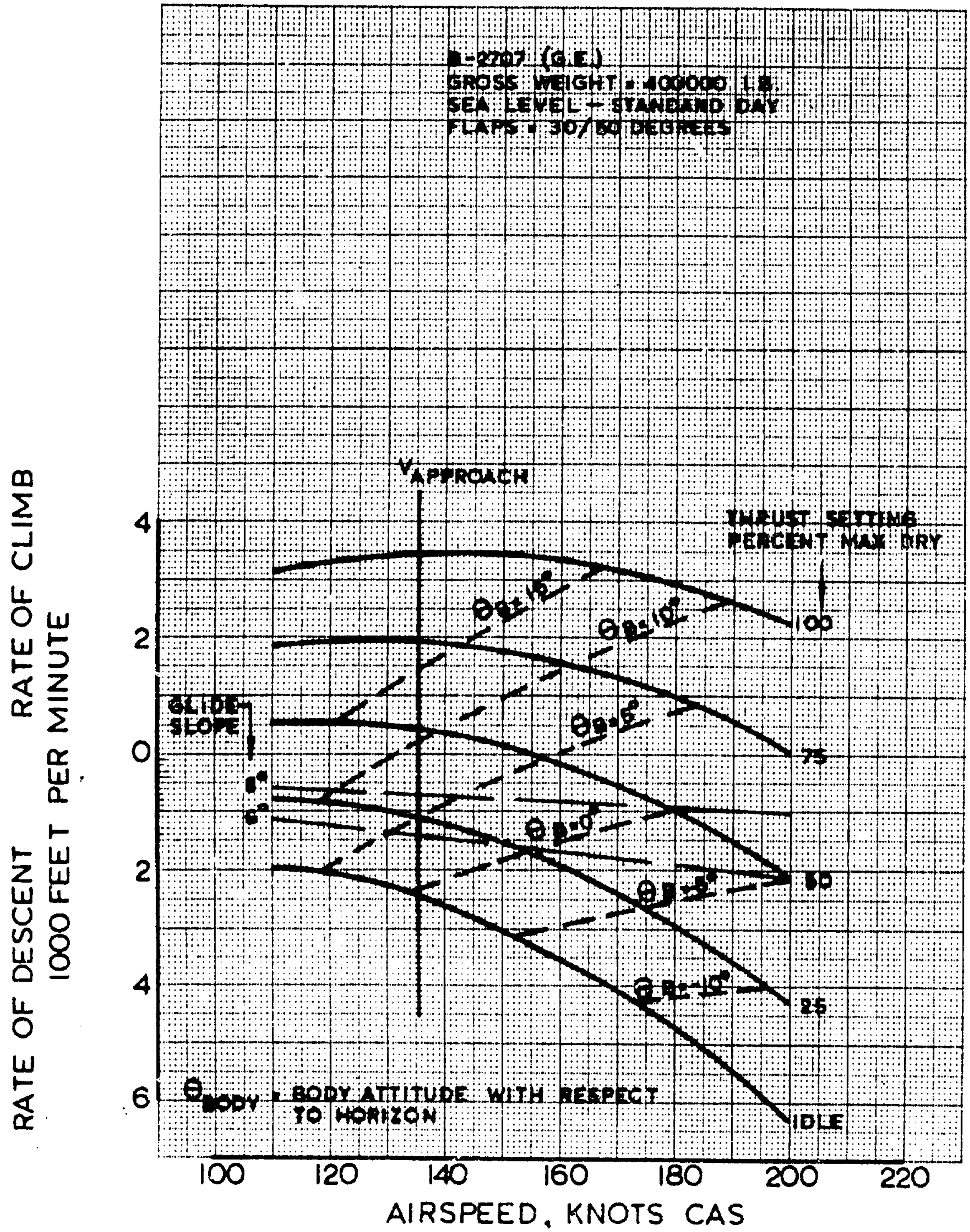


Figure 2–54. B–2707 (GE) Landing Approach Performance

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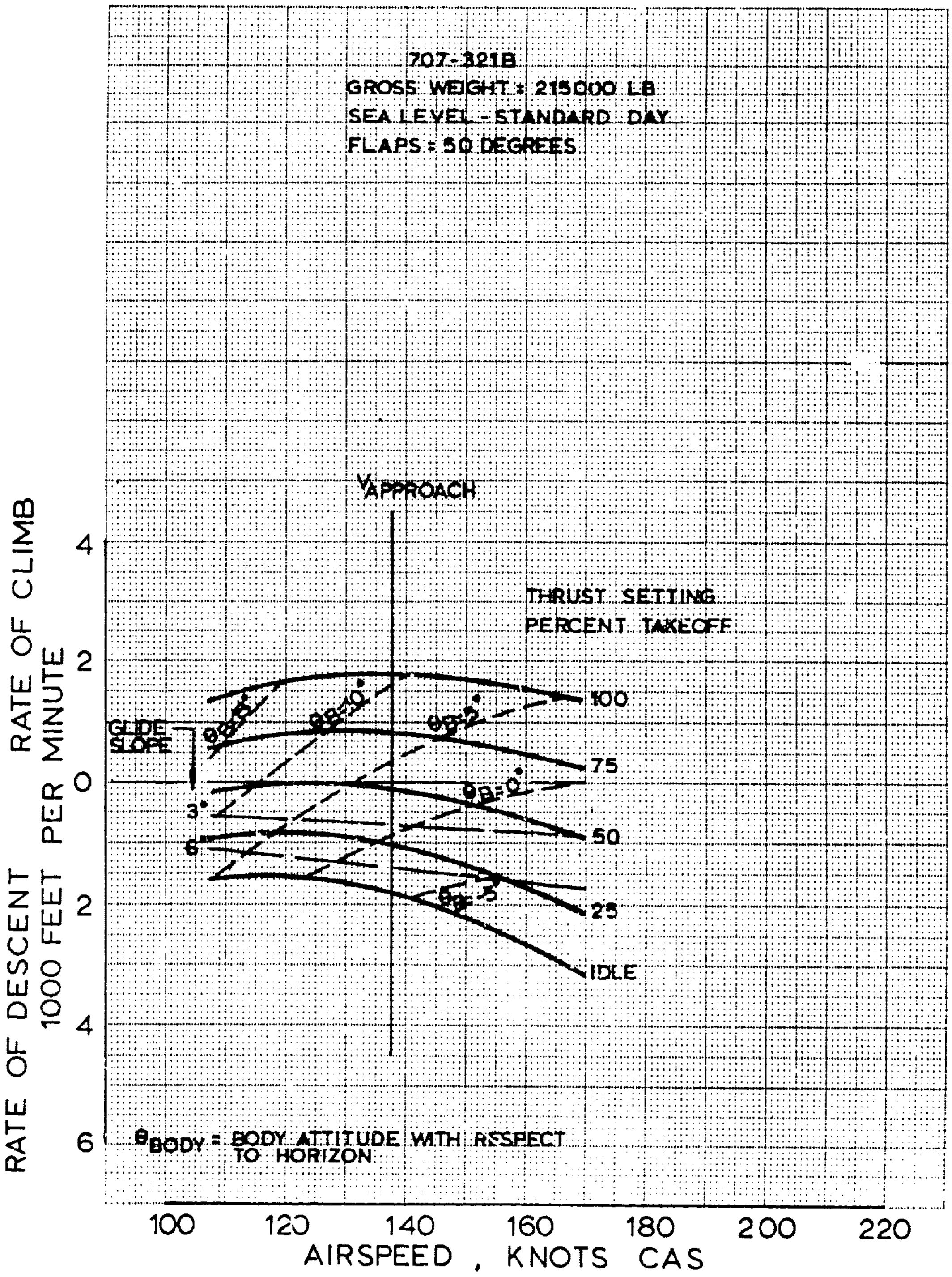


Figure 2–55. 707 Landing Approach Performance

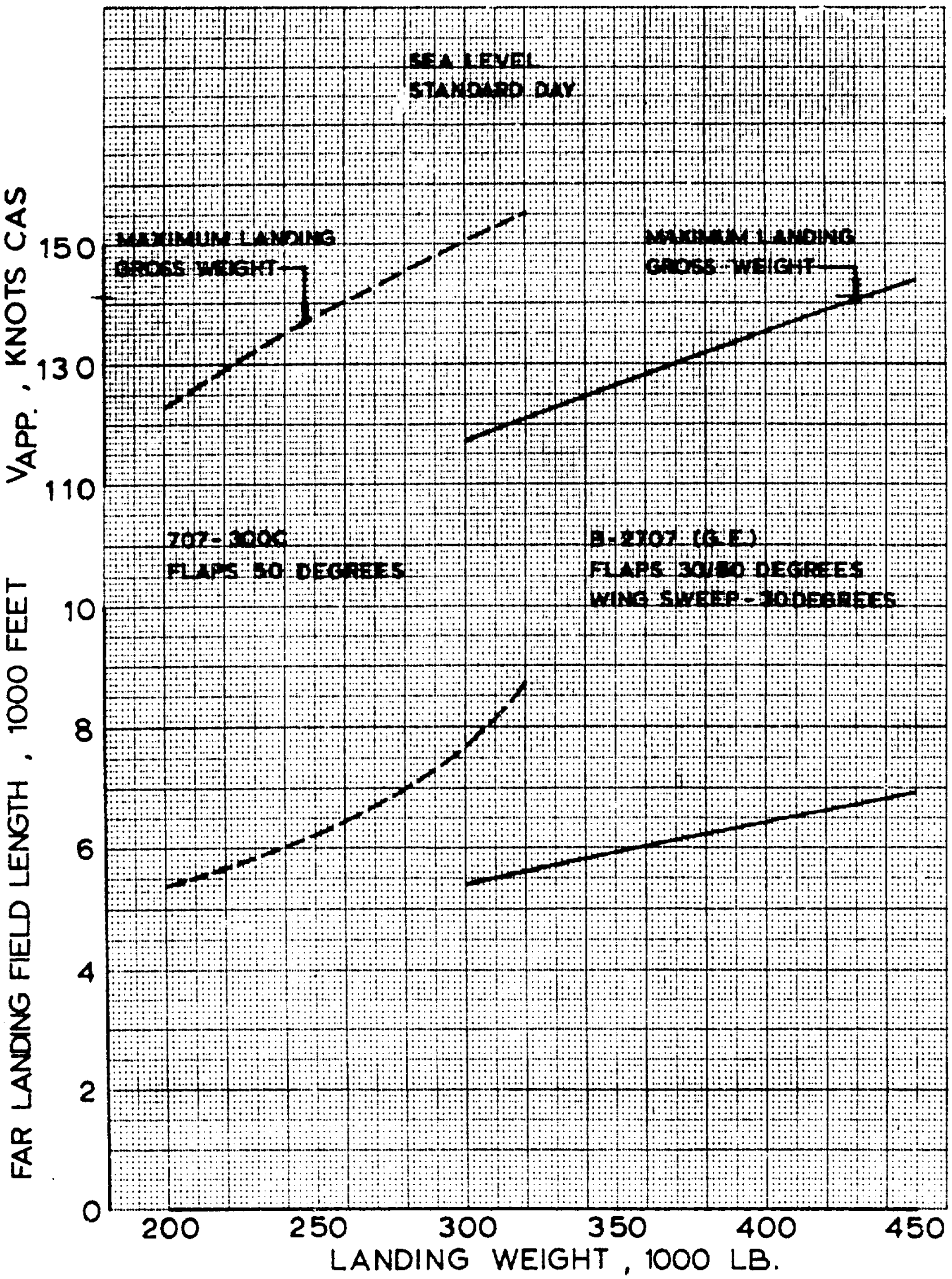


Figure 2-56. Landing Comparisons

V4-B2707-1

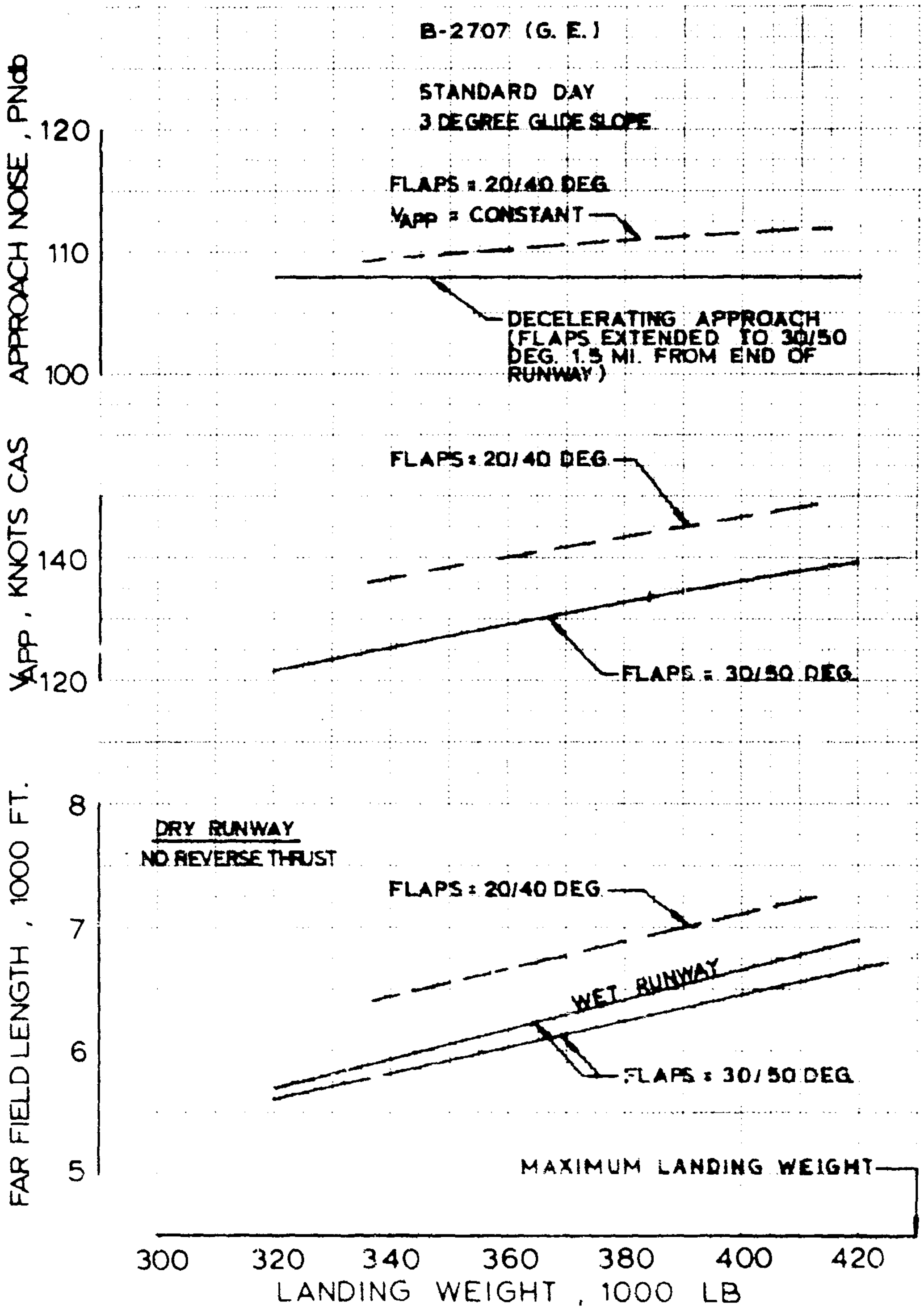


Figure 2–57. Landing Performance

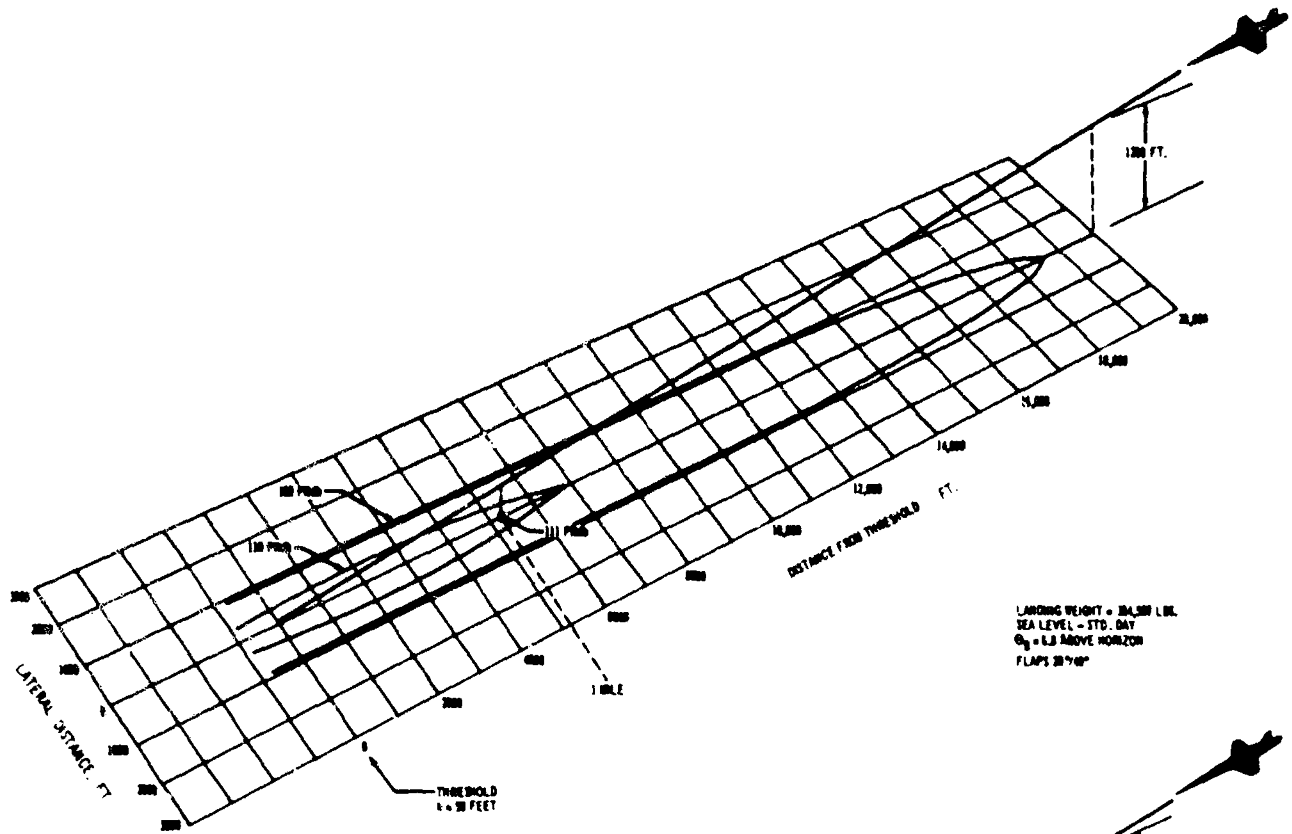


Figure 2-58. Landing Noise Contour With No Noise Abatement (GE Engine)

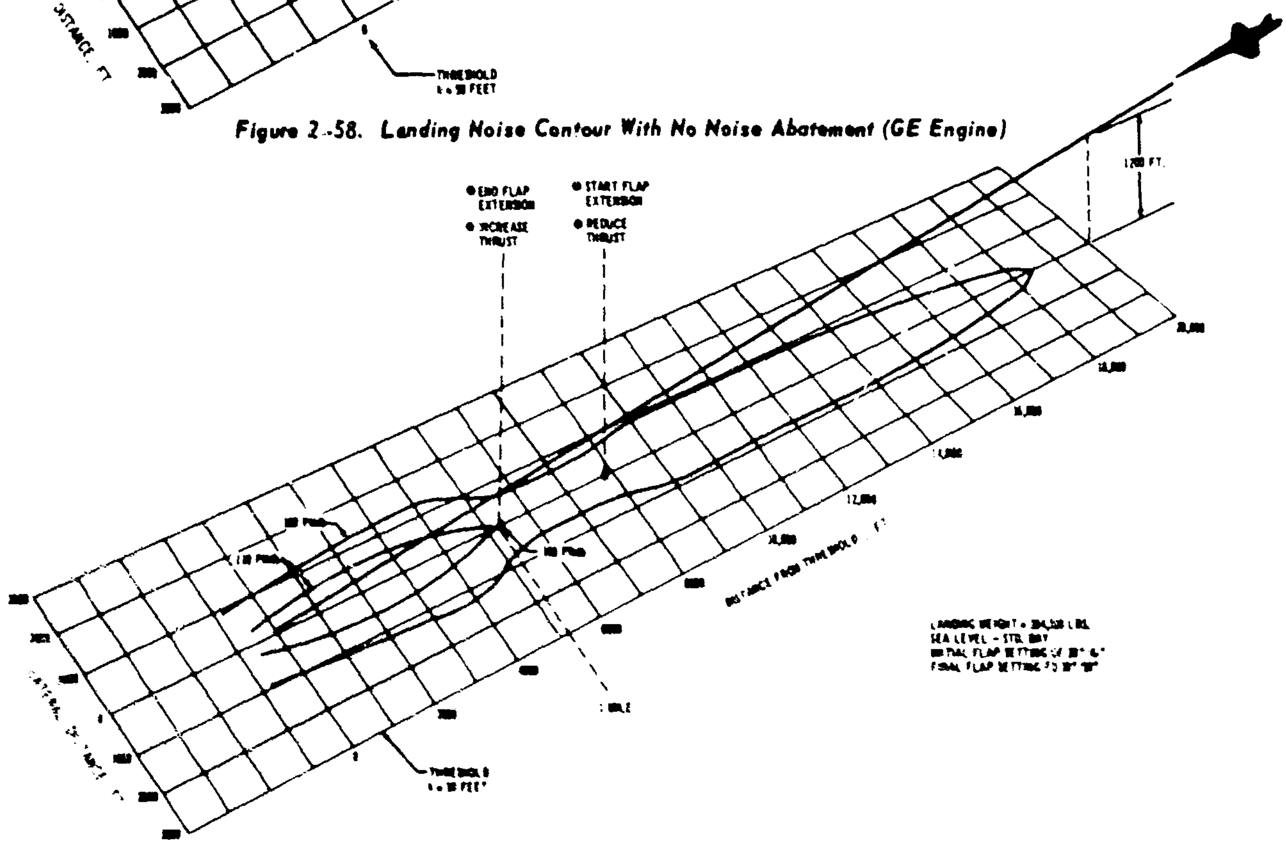
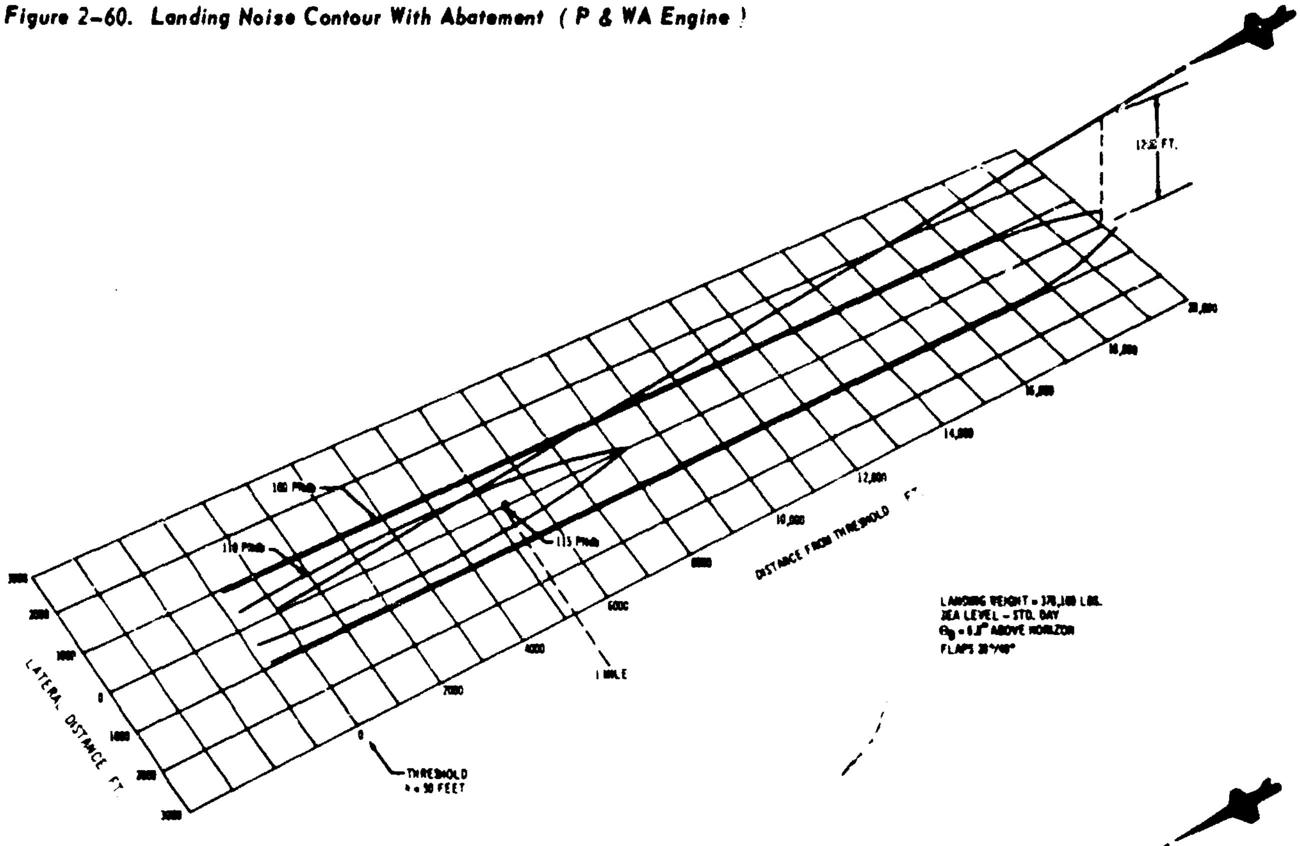


Figure 2-59. Landing Noise With Abatement (GE Engine)

Figure 2-60. Landing Noise Contour With Abatement (P & WA Engine)



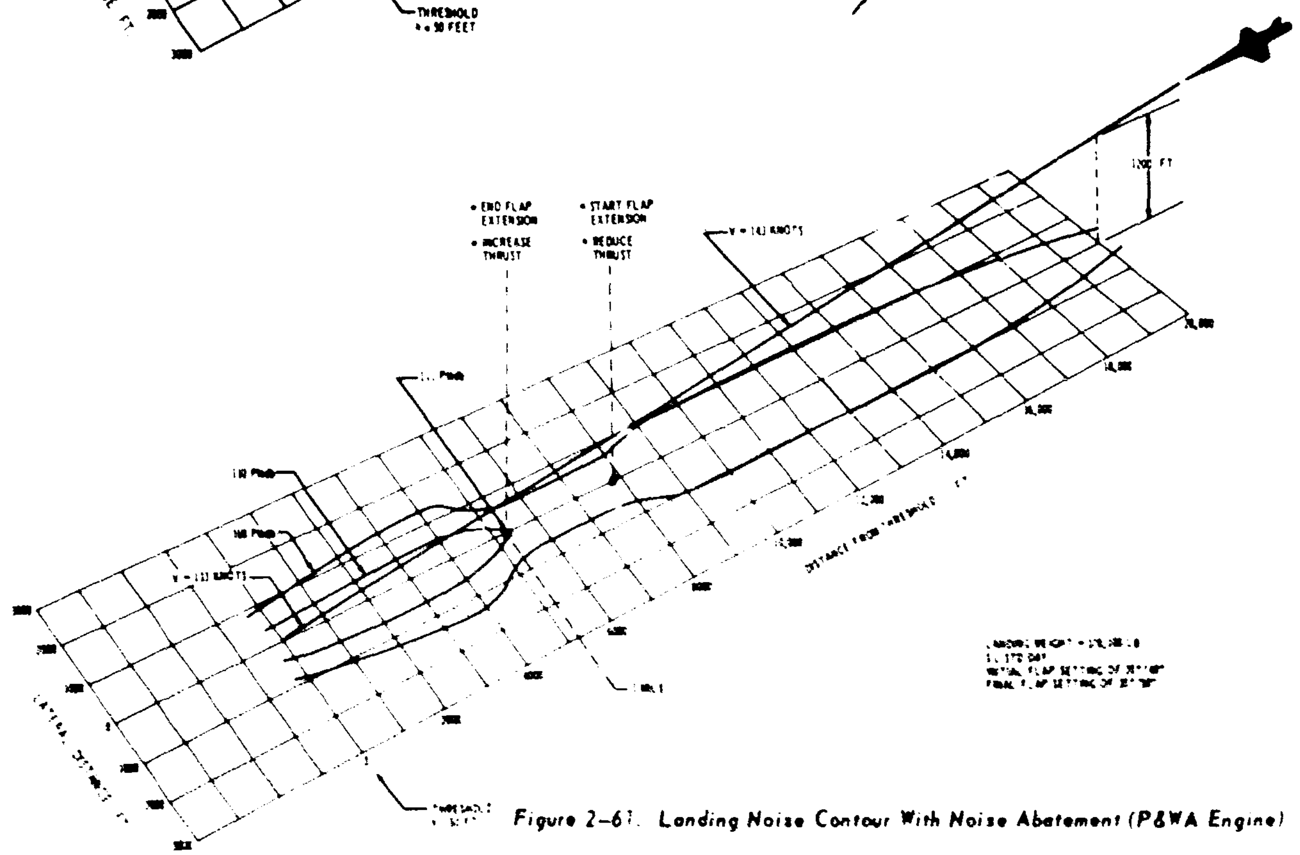


Figure 2-61. Landing Noise Contour With Noise Abatement (P&WA Engine)

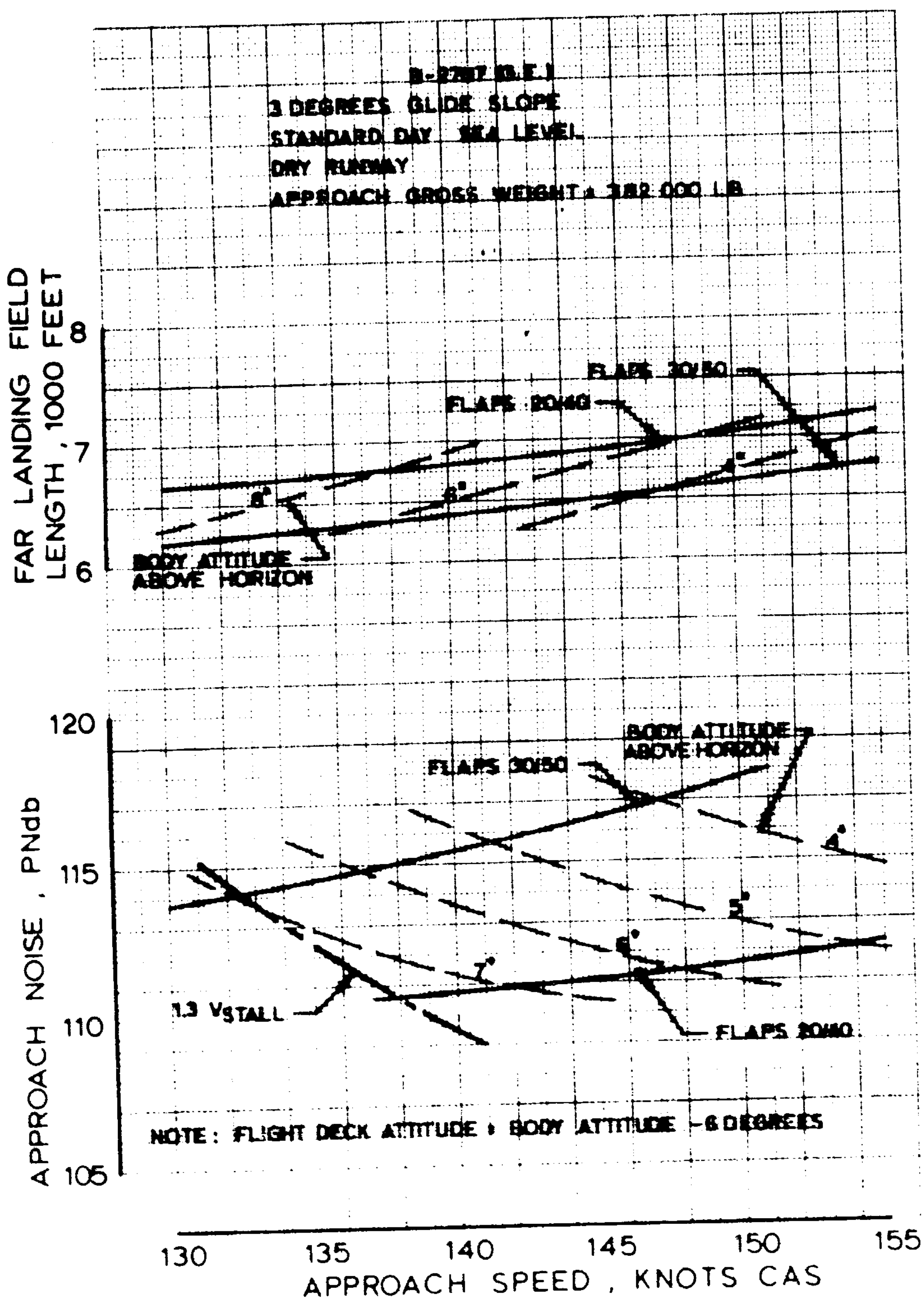


Figure 2-62. B-2707 (GE) Landing Noise Trades

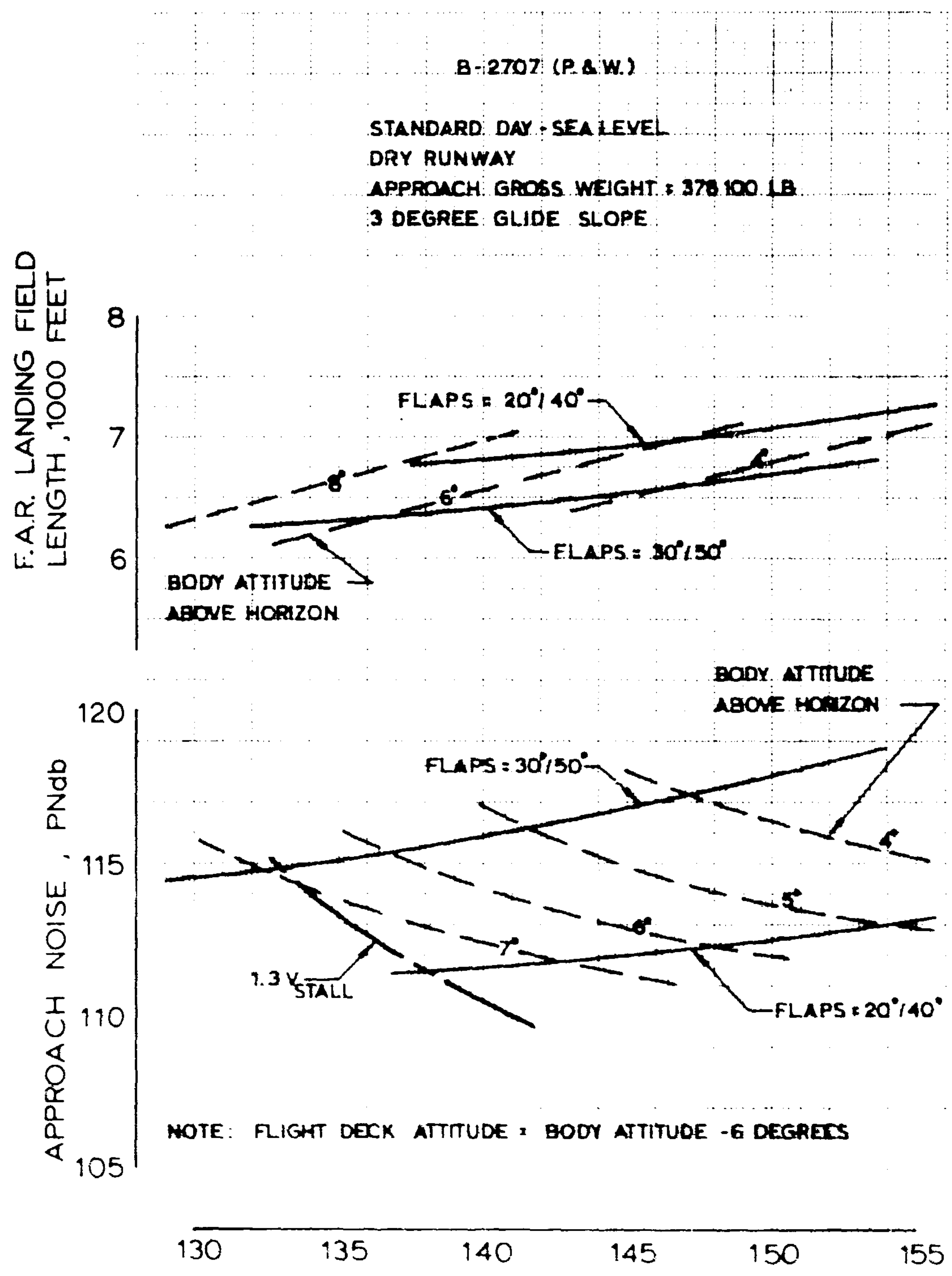


Figure 2-63. B-2707 (P&WA) Landing Noise Trades

The land position on the mode selector panel is selected prior to intersecting the localizer. The localizer, glide slope, flare and go-around light on the approach progress display is amber in the arm condition. After selecting the land mode the heading select control is used to maneuver the airplane until it reaches the desired position to begin the localizer capture. After localizer capture, the VOR/LOC light on the approach progress display turns green and the system automatically captures and tracks the localizer. When the airplane intersects the glide slope beam, either from below or above, the system automatically capture and track the glide slope. The glide slope light will change from amber to green.

At a flare altitude of 75 ft, the flare light turns from amber to green and the flare coupler controls the airplane to touchdown.

The pilot follows normal gear and flap procedures and selects the desired airspeed on the auto-throttle control panel. The auto-throttle system holds the desired airspeed until flare. During flare the auto-throttle system reduces airspeed as a function of altitude.

Flight tests on the 707 airplanes have shown that de-crab prior to touchdown is not required for crab angles less than 10 deg. However, manual de-crab is possible through the rudder pedals, because the autopilot and stability augmentation signals are introduced to the rudder through a series of actuators. Runway rollout is controlled manually.

The automatic flight control system has a go-around mode which can be initiated, after arming, by a switch on the throttle levers. The go-around system rotates the airplane for climbout with a minimum altitude loss after initiation of the go-around. Throttle control is manual during go-around mode.

The automatic flight control system and the auto-throttle system control the airplane to touchdown in the atmospheric conditions specified in the current FAA standard and maintain the airplane within ±35 microamps (1/2 DOT on the ADI) or 12 ft of the glide slope, 2.8 fps ±1 fps at touchdown, ±20 microamps (1/4 DOT on the ADI) of the localizer beam and, ±3 knots of the selected speed. A detailed discussion of the automatic landing system capability is contained in the Flight Controls and Hydraulics Subsystem Specification, D6A-10120-1. (See Fig. 2-64.)

2.8.3 Go-Around Capability

The 4- and 3-engine wave-off or aborted landing capability at maximum landing weight, and the minimum control speed for this condition is shown in Fig. 2-65. Less than full rudder will be required in the event of a go-around with one engine out. The 3 engine rate-of-climb is impressive even with landing flaps. Climb gradients in excess of 9 percent are available at maximum landing weight with 3 engines at maximum dry thrust.

2.8.4 Handling Characteristics

The low speed pitch characteristics in the landing configuration have been studied on the Boeing and NASA-Ames simulators. Angles of attack up to 35 deg have been accurately simulated along with estimated effects out to 50 deg angle of attack. The most recent data indicates the C_L maximum is reached without stick force reducing to zero. Beyond C_L maximum, a very minor pitch-up is noted which can be easily checked at any point with small nose-down elevator application. The fact that the airplane is controllable to all angles of attack up to 40 deg indicates that there is no "deep stall" problem.

The trim changes due to flap extension, sweep angle variation, and spoilers are shown in Table 2-E in terms of elevon deflection. The trimming required during normal operation is very small. The SAS maintains longitudinal trim thus relieving the pilot of frequent trim changes.

The lateral-directional dynamic stability and handling characteristics of the B-2707 are considerably better than present-day commercial jets. There is practically no dutch roll evident in approach and landing configurations. The airplane shows very little tendency to sideslip or yaw adversely during turn entry. The dihedral effect is very low so no rolling motion is generated by the slight adverse sideslip. Roll damping is good.

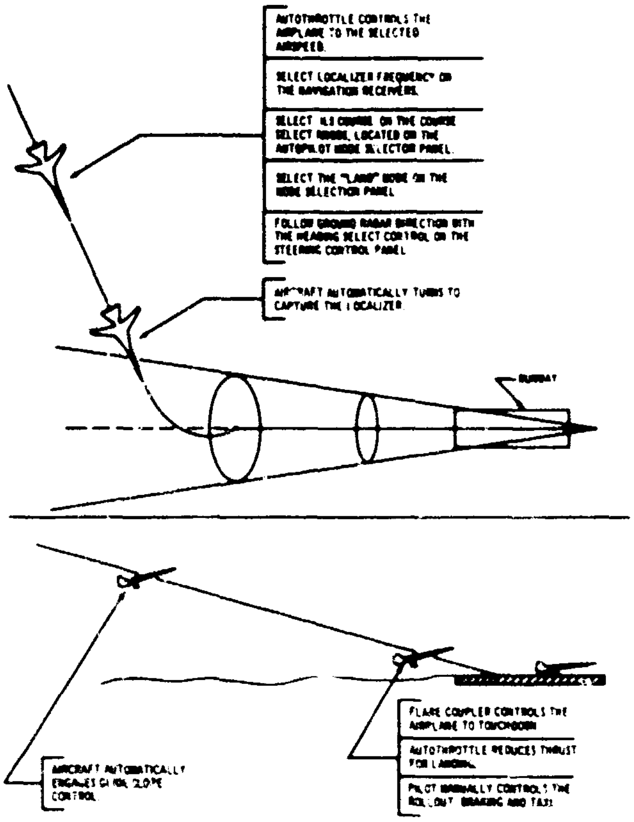


Figure 2-64. All-Weather Capability

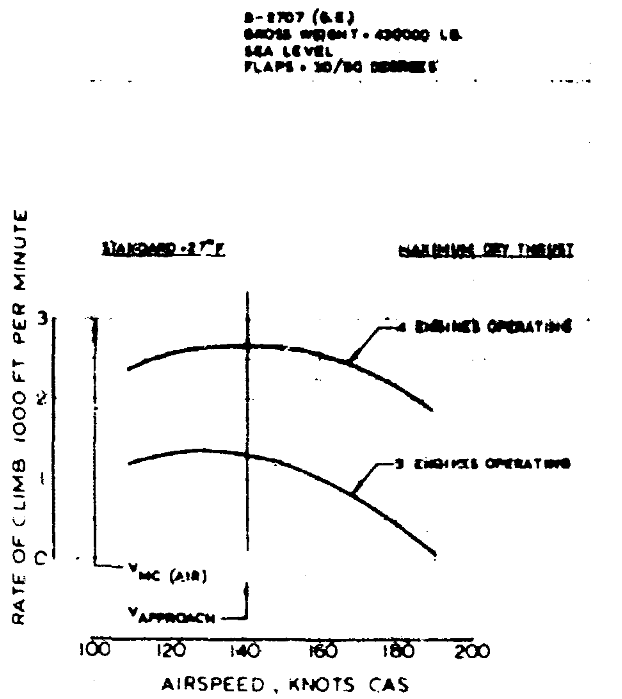


Figure 2-65 Go-Around Capability

In addition, the SAS off characteristics appear to be satisfactory in that no difficulty is encountered in performing an ILS on instruments to touchdown with deviation data alone. Turbulent weather conditions may dictate an SAS off ILS limit of 100 or 200 ft. However, flight director assistance is of some value in this remote situation which occurs after three failures.

The airplane handles well in crosswinds because of the low dihedral effect and the effective rudder. The low side force characteristic is also favorable in crosswinds because it reduces cross track drift during the de-crab maneuver.

A maneuvering capability of 1.5 g is available during approach, and the landing flare and touchdown is normally accomplished with a body attitude change of 1- to 2-deg nose up. The touchdown occurs at an attitude of approximately 7 deg. The ground interference body angle is 11.5 deg with the landing gear struts extended. Simulator studies show that the flare characteristics of the airplane with SAS off are sluggish, but no difficulty was experienced accomplishing normal landings. The necessary attitude change is small because of ground effect so that the sink rate is readily arrested with small elevon deflection 80- to 100-ft above the ground. This compares with a similar elevator input at 60 ft above the ground for the 707-320.

2.8.5 Landing in Non-Standard Conditions

The landing performance of the B-2707 is much less critical to non-standard conditions than today's subsonic jets. The effects of high ambient temperature and landing on wet or icy runways are discussed in the following paragraphs.

High temperature causes an increase in approach true airspeed, at the normal approach calibrated airspeed, which increases field length and braking requirements in the same degree as for subsonic jets. Available go-around thrust is also less on a hot day, but it is more than adequate for safe

Table 2-E. Longitudinal Trim Changes

Initial Trim Conditions				Configuration Change	Parameter Field Constant	$\Delta\delta_e$ Trim Change	
Configuration	Speed	Thrust	Flaps			Fwd cg 58% C_R (Degree)	Aft cg 62% C_R (Degree)
Maximum Landing Weight Λ_{LE} = 30 degrees	1.4 V_S (189.5 kn)	Off	Up	Extend landing flaps	1.4 V_S	-10.4	-1.5
	1.4 V_S (157 kn)	Off	Landing flaps	Retract flaps	1.4 V_S	+10.4	+1.5
	1.4 V_S (189.5 kn)	Off	Up	Max augmented to takeoff thrust	1.4 V_S	+2.0	+2.0
	1.4 V_S (157 kn)	Off	Landing flaps	Max augmented to takeoff thrust	1.4 V_S	+2.5	+2.5
	1.4 V_S (157 kn)	Off		Gear down	Speed	Negligible	
	1.3 V_S (145.8 kn)	Off		Max dry thrust Retract flaps = max L/D	Altitude	+12.2	+3.5
	1.4 V_S (157 kn)	Off		Speed change to 1.1 V_S (123 kn)	Altitude	-5.4	-1.25
	1.4 V_S (157 kn)	Off		Speed changes to V_{FE} (195 kn)	Altitude	+5.9	0.25
Gross weight = 627,000 lb Λ_{LE} = 30 degrees	V_e = 230 kn (1.4 V_S = 20)	On	Up	Sweep wing to Λ_{LE} = 72°	Maintain climbout acceleration (ΔV = 115 kn)	0 (cg 59% C_R)	-2.5

operation, even on three engines without thrust augmentation. No change in operating technique results from "hot day" conditions.

Thrust reversers are used to compensate for reduced wheel brake effectiveness on wet or icy runways. The distance over a 50-ft obstacle on a wet runway with four engines in reverse thrust is slightly less than the normal dry runway FAR field length. The reverse thrust is very responsive and effective, and convenient to the pilot. Thrust reversers, ground spoilers, and available wheel braking are initiated after touchdown with the airplane in a three-point attitude. Full reverse thrust is maintained down to 60 knots. Reverse thrust is used at reduced engine rpm below this speed.

2.9 ABNORMAL OPERATIONS

Propulsion and cabin pressurization failure conditions are discussed in Par. 2.6.4.

2.9.1 Three-Engine Landing

Normal approach and landing techniques and speeds should be used on three-engine landings. Partial reverse thrust should be used; full reverse thrust may be used on symmetrical engines. Adequate directional control is available with nose wheel steering after touchdown to relatively low taxi speeds. This condition is further discussed in Pars. 2.8.1.2 and 2.8.3.

2.9.2 Wing Sweep System Malfunction

The wing sweep actuating system has three independent hydraulic power sources and incorporates dual structural load paths and dual actuating torque tubes. One hydraulic motor will drive the wing swing sweep at 1/3 speed. Failure of the wing sweep mechanism is, therefore, considered very unlikely.

Landing the B-2707 with the wings swept aft (72 deg) is very similar to landing a present-day subsonic jet with the flaps retracted. The recommended approach speed for a Boeing 707-320 for a flaps-up approach on a 3-deg glide slope is approximately 180 knots. The B-2707 may approach with the wings 72 deg at 205 knots. To minimize the approach speed, fuel is used or jettisoned to reach a wings-aft landing weight of 350,000 lb. With the wings in the 72 deg position, no trailing edge flaps and only the leading edge strake slat is extended. Positioning the alternate slat lever extends the inboard slats to 25 deg and increases available rudder to 12 deg. Longitudinal dynamic stability is similar to that of current subsonic jets during their normal landing approach, and no longitudinal stability augmentation is required. Without stability augmentation, dutch roll damping is similar to that of the unaugmented subsonic jets. The augmented B-2707 is considerably better than current stability augmented subsonic jets because the turn coordinator and yaw damper will aid in maneuvering the airplane by eliminating induced sideslip during turns and rough-air flight conditions.

Maneuvering load factors up to 2 g can be attained at 205 knots for the forward cg limit case, which is more severe than at normal cg. A large margin of excess thrust is available at this approach speed. The variations of thrust and drag with speed are slightly unstable; however, simulator tests have shown that glide slope control is not difficult. With wings aft, standard day, wet runway, the landing distance over a 50-ft obstacle is 6,000 ft when utilizing 4 engines in reverse thrust (Fig. 2-66).

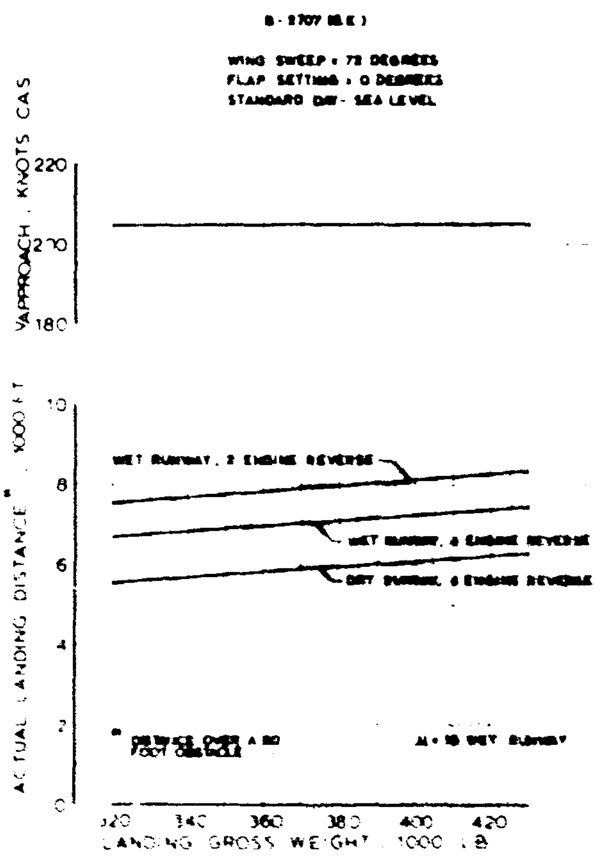


Figure 2-66. Landing Performance

Electric sensors on the wing pivot, flaps and slat positions. sense motion at symmetrically opposite locations on the airplane. An electrical comparator is connected to a hydraulic system for asymmetric protection. Manual override is provided for malfunctions of the wing sweep asymmetry protection. A separate sensor is used for measurements at each surface for flight deck instrumentation.

The wing sweep programmer controls the wing sweep drive unit and schedules the translation of trailing edge flaps and partial extension of the leading edge slats. If the wing sweep fails to move because of an asymmetry control trip, it can be overridden by the wing sweep asymmetry override switch. The procedure is as follows:

a. Use normal sweep speed schedule.

b. Select desired sweep control lever position.

c. Move wing sweep asymmetry override switch to desired fore or aft position. (This switch is spring loaded and must be held until the sweep matches the position called for by the wing sweep lever.)

d. Monitor the pilot's control wheel and wing sweep indicator for normal roll response.

2.9.3 Loss of Stability Augmentation
The unaugmented B-2707 is flyable throughout the operating range without stability augmentation. In the regions where instrument requirements are the most stringent, namely area departure, climbout, subsonic cruise, arrival, approach, and landing, the unaugmented B-2707 is slightly more sluggish in pitch and similar in lateral-directional characteristics to current large jet airplanes. The stability augmentation system refines the airplane free dynamic stability and handling qualities. These refinements are ensured even with a single augmentor failure. Triple augmentation channels are provided in pitch, roll, and yaw axes. A fourth electronic channel is provided in the pitch and yaw axes. If a channel fails, the augmentation authority will not be reduced. Since the gain in the remaining channels will be stepped up to compensate for the loss. The first failure of a single system does not disengage the SAS, but the failed system automatically shuts off. A second failure will disengage the SAS, but the airplane will remain in trim.

2.9.4 Three-Engine Ferry
The three-engine-ferry takeoff analysis shows the ability of the airplane to take off on 3 engines at maximum dry thrust at a weight of 550,000 lb with a FAR field length of 9,200 ft. At this takeoff weight the B-2707 (GE) will have a subsonic ferry range of 2,640 nmi. This range is based on having no payload for the flight. The subsonic cruise would be conducted with a wing-sweep angle of 42 deg at Mach 0.85. The cruise altitude would be approximately 35,000 ft. In actual practice, when rudder becomes effective (Table 2-B), the 3 engines could be brought up to an augmented takeoff thrust setting during the ground roll, improving takeoff performance considerably.

2.9.5 All-Engine Out Operation
The B-2707 M_{MO} or normal descent schedules may be used in the four engine inoperative flight condition. These schedules superimposed upon the engine relight envelope are shown in Fig. 2-67. The figure indicates that an engine relight is possible at any point along the descent schedule, with windmilling engines and with or without boost pumps (GE). It may be necessary to descend below the normal schedule for engine restarting with the P&WA engines (Fig. 2-68).

The P&WA engines provide adequate windmilling power down to and including landing flare, should all engines fail. The GE engines provide sufficient windmilling power down to an airspeed of Mach 0.75. Below this speed, supplementary hydraulic power is provided by means of a ram air turbine.

Electrical power, except for engine ignition, is provided by a battery-inverter combination. Engine ignition is supplied from a separate power supply which is capable of developing sufficient power from the generators at windmilling speeds.

The P&WA engines provide the means to distribute the hydraulic loads to obtain optimum usage of the hydraulic power available from the windmilling engines during the all-engine out situation. The hydraulic loads are distributed among the three hydraulic systems by selectively closing the electrical shutoff valves in two of the three power systems on each of the flight power control units. This is accomplished by the ALL ENGINE OUT HYDRAULIC POWER switch on the aft end of the aisle stand which is in series with

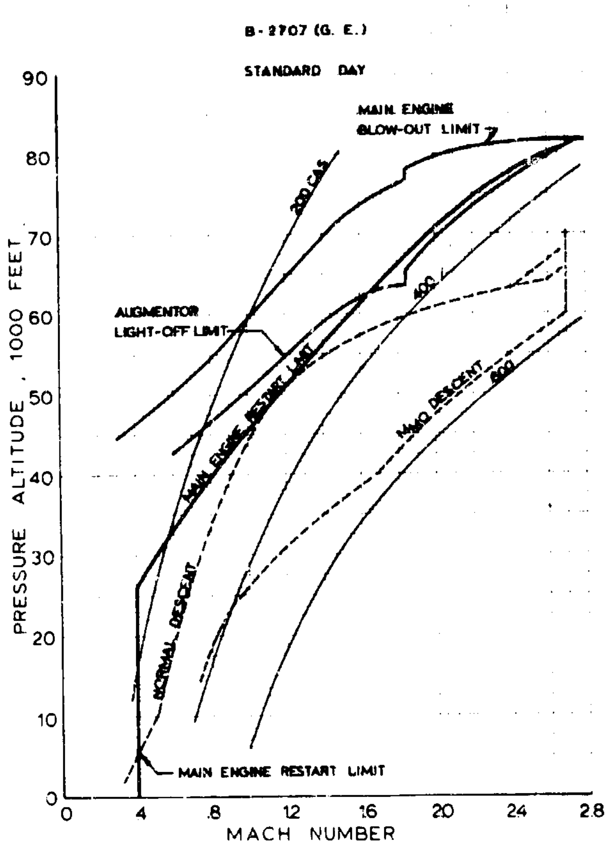


Figure 2-67. B-2707 (GE) Engine Restart Schedule

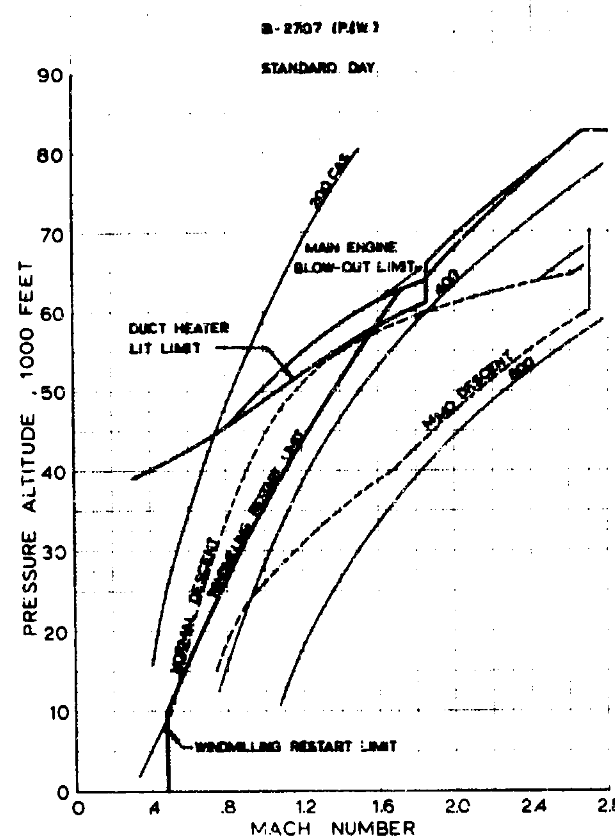


Figure 2-68. B-2707 (P&WA) Engine Restart Schedule

the normal control circuits to the shutoff valves in the power control units.

The air-turbine-driven pump is connected to system B hydraulic supply and pressure lines to provide supplementary hydraulic power during the all-engine out situation. The turbine is extended and retracted by a hydraulic actuator and is operated by the ALL ENGINE OUT HYDRAULIC POWER switch.

2.9.6 Landing Gear Malfunctions

The landing gear is normally powered by hydraulic system C. Any gear can also be operated by the standby hydraulic system. The standby hydraulic system is powered by B system with electrical power backup. Should both hydraulic systems fail, the nose gear and both forward main gear will free fall to the down and locked position.

The main gear system hydraulic manifold equalizes shock strut loads, keeping the centroid of the main gear supporting forces aft of the center of gravity of the airplane so that the nose wheel always has a load. The four main landing gear "trucks" provide a higher degree of safety because of the inherent redundancy of the four independent gears in the event of a main gear malfunction. In the event one gear does not extend, its manifold to the other gear would not function. There would be a minor change in nose-wheel load, but no significant pitching tendency. A normal landing can easily be accomplished with the nose gear and any three main gears extended.

2.9.6.1 Main Landing Gear Malfunction

The airplane can also be landed safely with either forward or aft gear pairs in the retracted positions.

If the landing is made with the two aft gears retracted, the airplane may tip back gently on the tail skid (ventral fin) after the airplane has been stopped, if nothing is done to prevent this. Normal wheel braking and elevator control will hold the nose down until the airplane comes to a full stop.

A safe landing can also be made with the nose wheel, one forward and opposite aft main gear extended.

2.9.6.2 Two Main Gear on Same Side and Nose Gear Extended
The wingtip will contact the runway as aerodynamic control decreases below that required to hold wings level. Directional control can be maintained by a combination of nose and main gear steering and wheel braking. Minor damage will occur to the wingtip.

2.9.6.3 Nose Gear Up - All Main Gear Extended
Normal approach and landing technique should be used with only the main gear extended and the forebody (movable nose section) extended to the full down position. The forebody will serve as a skid local deformation of the forebody and will absorb the landing impact at the nose so that the loads in the basic structure, including the flight crew compartment will not exceed the design strength.

2.9.6.4 Nose Gear Extended - Main Gear Up
Approach and land at normal speeds. The airplane will touch down on the ventral fin (tail skid), engine pods, and nosewheel. Minimum structural damage will occur to the airplane. Spark ignition hazard is minimized by confining spark generation to the ventral fin which is aft of the fuel areas.

2.9.6.5 No Gear Extended
Approach and land at normal speed. The airplane will touch down on the ventral fin and engine pods. The forebody will contact the ground and absorb the energy as described in Par. 2.9.6.3.

2.9.6.6 Wheel Brakes Failure
All wheels are equipped with an anti-skid system with each wheel individually controlled. The loss of two brakes on one side will only slightly effect directional control. The loss of two brakes does not significantly affect braking performance.

2.9.6.7 General Considerations
Landing gear malfunctions occur occasionally on all airplanes. The pilot's decision will be influenced by the circumstances. The available landing gear configurations combined with the structural and system integrity provide the pilot with a level of redundancy and safety much higher than present-day commercial transports.

Should the ultimate gear design loads be exceeded during landing, the gears are designed to fold aft about their normal trunnion axis as follows: the rear gears fold aft into their normal stowage cavities; the front main gears fold aft under the structural wing box; the nose gear will fold aft under the body.

Fire hazard from spark ignition is remote because the nose wheel is far forward of the fuel areas. Failure of the main landing gears will not damage the primary wing structure containing fuel.

2.9.7 Wing Flaps and Slat Malfunction
High-lift devices are: inboard wing trailing edge flaps, outboard wing trailing edge flaps, inboard wing slats and outboard wing slats. The wing flap control level and wing sweep control lever operates through the flap-wing sweep programmer which provides mechanical scheduling of sweep and high-lift systems.

Fore and aft translations for the outboard wing flaps are controlled by the wing sweep control lever. Rotation of the outboard wing flaps and operation of the inboard flaps (fixed wing) are controlled by the wing flap control lever.

The inboard flaps (fixed wing) and inboard and outboard slats operate from two hydraulic systems. The outboard flap systems operate from three hydraulic systems. All high-lift devices are symmetrically driven through separate gear boxes and torque tube systems. Asymmetry detection and control is provided without override capability.

Failure of any high-lift device to operate as sequenced does not prevent the wing from being positioned to the forward-sweep position.

Possible wing flap failure situations are as follows: (1) loss of inboard flaps (fixed wing) and

loss of inboard and outboard slats results from simultaneous loss of hydraulic systems A and C; (2) split of either movable wing flap systems could result from a failure of the torque tube or ball screw drive unit. The only action required by the pilot is to add the appropriate correction to the approach speed.

2.9.8 Primary Flight Control System Malfunction
The primary flight controls consist of elevons; primary elevators and auxiliary elevators for longitudinal control; ailerons and spoilers for low-speed lateral control; elevons and spoilers for high-speed lateral control; a rudder for directional control. The elevons are used for longitudinal control with wing flaps extended. During supersonic flight the elevons are operated differentially for lateral control and symmetrically for longitudinal control. All control surfaces are actuated by three independent hydraulic sources except the auxiliary elevators which are dual.
Normal operation of the control column produces a signal which is sensed by force transducers and fed into the electric command system (E/C). The E/C system modifies these commands according to the flight conditions and produces an electric signal to the longitudinal and lateral master servos. The servos drive the surface actuators and backdrive the control column through dual cable systems in the direction of the applied force. The cable system from the control column to the master servos is the alternate method of operating the primary control system. The cable system has force authority over the electric command system.

If loss of one of the three hydraulic systems occurs, the airplane can be flown at all speeds. The airplane can be flown at subsonic speeds with the loss of two hydraulic systems; however, continued operation is not recommended. To guard against possible adverse effects of a second failure at supersonic speeds, it may be necessary to decelerate to subsonic speeds. Continued supersonic operation after a single hydraulic system failure is a design objective of Phase III. Programs to effect this capability are discussed in the Aerodynamics Design Report, V2-B2707-3, Secs. 4.0 and 5.0.

In the event of a failure of the electric command system (E/C) normal operation is maintained with a single channel failure - no pilot action is required.

Failure of the second E/C channel in an axis requires the pilot to determine which of the channels has failed and then he must manually select the channel functioning properly.

Should all three E/C channel fail in one axis, the airplane can be operated normally through the autopilot or through the cable system, with an increase in control column force on the axis affected by the E/C failure.

The flight control system is designed with multiple backup capability in each axis. Should an abnormal condition occur on one control axis, the first and normal response by the pilot should be to apply opposite control to stabilize the airplane. Dual load path design in the mechanical systems with override devices permits the pilot to use whatever forces he considers necessary to free a jammed or malfunctioning control surface.

2.9.9 Environmental Control Abnormal Operation
Any three of the four air-conditioning units will provide adequate cooling and ventilation for a fully-loaded airplane. If an engine is shut down, the affected accessory drive system (ADS) and cabin air compressor can be operated by bleed air from the operating engines. If the cabin air compressor is inoperative, the air-conditioning unit can be operated with engine bleed air. Individual electrical override control is provided for the temperature control valves in case of an inoperative automatic temperature controller. Electrical override is also provided for the ram air doors that control the amount of coolant air flow across the heat exchangers. If two air-conditioning units are inoperative, the airplane will be decelerated to subsonic cruise.

If the automatic pressurization control is inoperative, the out-flow valves may be positioned electrically from the flight deck by use of the manual pressure controller. In the event that cabin altitude is increasing, the intrawall exhaust is closed to minimize the loss of cabin pressure.

2.9.10 Flight Deck Oxygen System
Crew oxygen is available for use in case of a loss in pressurization or smoke in the flight deck. Quick donning masks are stowed at each flight deck crew station. In the event that crew oxygen is required, the crew members will don their mask and select either 100-percent oxygen or diluter-demand. The 100-percent position is

used when there is smoke in the flight deck.

2.9.11 Hydraulic System Abnormal Operation
The three main hydraulic systems (A, B, and C) have indicators and controls for identification and isolation of faulty components. If a single hydraulic pump low pressure light comes on, the pump is turned off and system fluid quantity and pressure are checked. In the event of a system overheat warning, the system pumps are turned off one at a time to isolate the faulty pump. (The effect of hydraulic system failure on flight control has been discussed previously.) If system C is inoperative, the landing gear and wheel brakes will operate from the standby hydraulic system.

If all four engines of the GE-powered airplane are inoperative, a ram air turbine can be lowered into the airstream and will provide sufficient hydraulic control power at approach speed. The P&WA powered airplane has sufficient hydraulic power from the windmilling engines to accomplish a landing flare.

2.9.12 Abnormal Engine Operation
An engine fire, low engine oil pressure, loss of engine oil, oil overheat reading, excessive engine vibration, or loss of steady fuel flow may require engine shutdown. The engine is shut down in flight by reducing the thrust setting to idle and placing the mode selector lever in the SHUTDOWN position. The automatic inlet control system will contract the centerbody to its least expanded configuration and open the bypass doors. A switch on the pilots' aft overhead panel actuates the engine windmill brake, thereby reducing the engine rpm.

In the event of engine fire, moving the thrust lever to idle and the mode selector to SHUTDOWN shuts off the engine fuel. Pulling the fire handle on the pilots' overhead panel shuts off the hydraulic fluid supply, engine bleed air, secondary air flow, and the ignition system, arms the fire extinguishing system and deactivates the generator. The fire extinguishing switch is located next to the fire handle. If the fire persists, a second source of extinguishing agent is selected and discharged.

If a complete hydraulic or electrical failure occurs in the automatic inlet control system, the centerbody will contract and the bypass doors will open. The inlet can then be controlled manually through the control knobs on the centerbody position and bypass position indicators on the flight engineers panel.

2.9.13 Abnormal Fuel System Operation
Inflight engine shutdown requires crossfeeding fuel from the inoperative engine's fuel tanks to the operating engines. To maintain the airplane's center of gravity within limits, the fuel in the inoperative engine's fuel tanks must be consumed by the other engines.

If a single fuel boost pump failure occurs, the inoperative pump is switched off and fuel is supplied with the tank's remaining boost pump or pumps. Failure of all boost pumps in any one tank requires the fuel manifold to be connected to any tank with operating boost pumps.

If all boost pumps fail due to a complete ac electric power loss, all fuel manifold valves are closed. With no boost pumps operating, the fuel feed system will still satisfy emergency engine fuel requirements. The engine fuel shutoff valves and the fuel crossfeed are battery powered when normal electrical power is not available, thereby permitting operation in an emergency.

The airplane is equipped with a fuel dump system. Dumping is accomplished by opening each tank's dump valves and the two dump nozzle valves, and then actuating the respective fuel boost pumps. The dump system will automatically shut off to maintain the required fuel reserves.

2.9.14 Forebody Abnormal Procedures
The movable nose section has provisions which prevent damage or faulty operation due to accumulation of water, slush, ice, or dirt. If one of the dual electric motors fail, the other motor will raise or lower the nose at a reduced rate (30 seconds). If the electric alternate system fails while the nose is in the up position, the nose can be lowered by manually disengaging the uplock and friction brake which allows the nose to free fall. A visual flight simulator study shows that landing the airplane with the forebody in the cruise position is possible.

2.9.15 Abnormal Electrical System Operation
Failure of one ac power source may require some nonessential load reduction. If two power sources fail, supersonic flight may be continued. To assure maximum system reliability, the remaining two generators are isolated by placing the bus tie switches to MANUAL OFF.

Supersonic flight cannot be maintained when three of the four generator power sources fail. Subsonic flight can be maintained since fuel boost pumps are not required for this operating condition.

In the event of loss of all generators in flight, the standby system automatically powers the battery bus and the inverter bus for 30 minutes. The inverter bus is capable of handling those loads essential to transition from supersonic to subsonic flight, controlled subsonic flight, and landing.

Impending failure of a generator may require disconnection from the ADS by placing a switch to the disengaged position.

In the event of smoke in the flight deck or passenger cabin, disconnect each part of the electrical system by operating the individual load bus switches. After the smoke source is located and deactivated, power may be re-established.

2.10 STALL SPEEDS AND CHARACTERISTICS

The stall speed with wings forward and flaps down is defined as the speed below which the maximum lift coefficient (C_L) develops lift equal to the weight. The approach to the stall is easily detectable in flight, as it is characterized by an excessive nose-high attitude, heavy buffet, some lateral-directional instability and an obvious sink rate. Simulator tests show that full thrust application will effect immediate recovery from any such unusual condition with practically no loss in altitude. The angles of attack associated with the apparent stall speed are in the 18- to 20-deg range, which in itself is a warning to the pilot. The stick shaker will also provide suitable stall warning. There are no adverse stall characteristics, such as pitch-up or sudden rolling tendency, evident in the angle-of-attack range up to stall, with wings forward and flaps down.

The flaps up stalls, with wings forward, have no adverse handling characteristics, but the minimum speed is less easily detected. With wings aft, the maximum angle of attack is not limited by wing stall as such. The angle of attack will exceed 30 deg without reaching maximum C_L's, but the drag will be increased significantly. Therefore, the minimum speeds with flaps up are based on a practical angle-of-attack limit considering airplane geometry, lateral control, and the regime of flight under consideration. For instance, in the case of wings-aft landing, the approach speed is based on a margin over the minimum practical speed, considering the pilots' visual angles and the tail contact body attitude.

2.11 PILOT VISIBILITY

The B-2707 flight deck and forebody configuration provides visibility comparable to or better than that provided in current large subsonic jet transports for landing, takeoff, and other airport traffic conditions (Fig. 2-69). The design to provide this visibility and the visibility at supersonic speeds is based on the requirements of the Federal Aviation Agency and the more stringent requirements proposed by the Society of Automotive Engineers (SAE) Committee on Flight Deck and Handling Qualities Standards to the SAE Aerospace Standard 580.

2.11.1 Transonic and Supersonic Visibility

The visibility guidelines are established by FAR 25, by the Tentative Airworthiness Standards for Supersonic Transports, and by the Proposed Revision A to the Society of Automotive Engineers Aerospace Standard 580. The Tentative Airworthiness Standards state:

"(c) Pilot compartment visibility provisions shall be established such that the pilot with normal and reasonable motion of the head and eyes will have external vision to the extent defined for the operating conditions listed below:

(1) All flight regimes. The pilots shall have sufficient view forward along the flight path and to the side to permit observation of cloud formations, other airplanes, and to provide visual orientation during normal flight or incidents involving attitude changes."

The proposed SAE AS 580 requirements state:

- "During transonic and supersonic flight, the pilot shall be provided with a minimum visibility of 3° above and below the flight path plan and 2-1/2° left and right of the zero azimuth, unbroken." Transition to the upper and lower angles of Par. 2 (Par. 2 of SAE AS 580 defines the subsonic upward and downward vision requirements outboard of straight ahead) should be achieved as quickly as possible as the azimuth moves outboard, and the visibility shall be unbroken to the maximum extent possible. In addition, "visibility shall be sufficient to provide

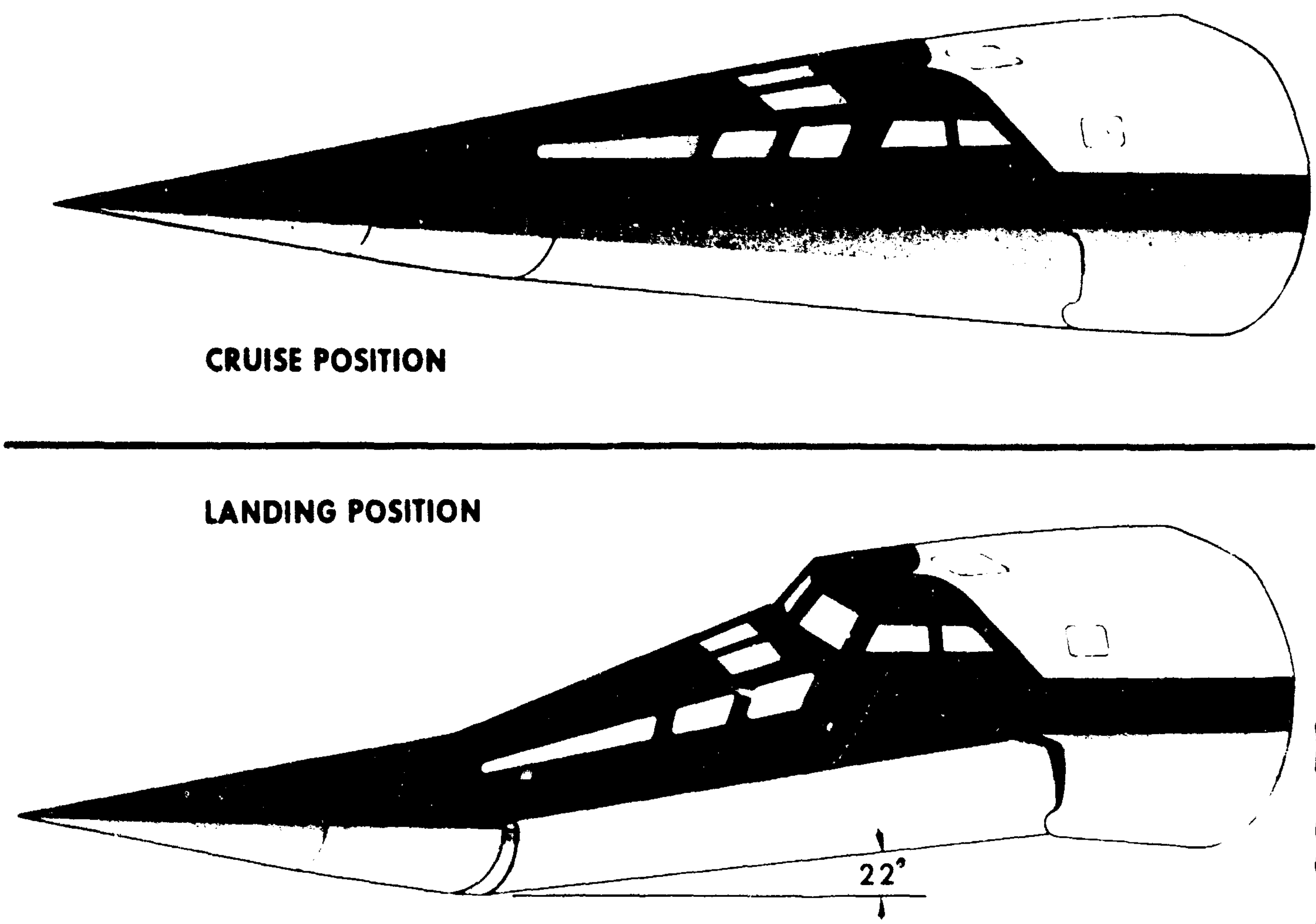


Figure 2-69. B-2707 Forebody

horizon reference during upset conditions involving combinations of pitch attitudes of 10° nose up to 20° nose down, and roll attitudes of 45° left or right of level.

- Artificial or indirect means may be used to augment the above; to offer visibility in excess of that above, for which direct vision is considered a requirement.
- Aircraft using fairings over the windshield shall provide for sufficient visibility to land the aircraft by visual reference, day or night, with the fairing in the supersonic position."

Dynamic simulator studies with participation by Airline, FAA, Military, and company pilots (Refs. 1 and 2) have led to the selection of transparency provisions which provide the field of view shown by Fig. 2-70 and illustrated by Figs. 2-71 through 2-76. Typical window structural features are shown on Figs. 2-77 and 2-78. The Airline Avionics, Flight Deck and Flight Operations Specialist Team have gone on record as stating: "Cruise visibility, as a practical compromise, is considered acceptable with the nose raised."

Extensive optical studies have been conducted in the laboratory and in flight (Ref. 3 and Fig. 2-79) to ensure that the design is satisfactory with respect to considerations of glare, distortion, reflections, and transmissibility, and attention has been focused on the detail design to ensure that there are no structural hot spots which would cause crew discomfort through localized heat

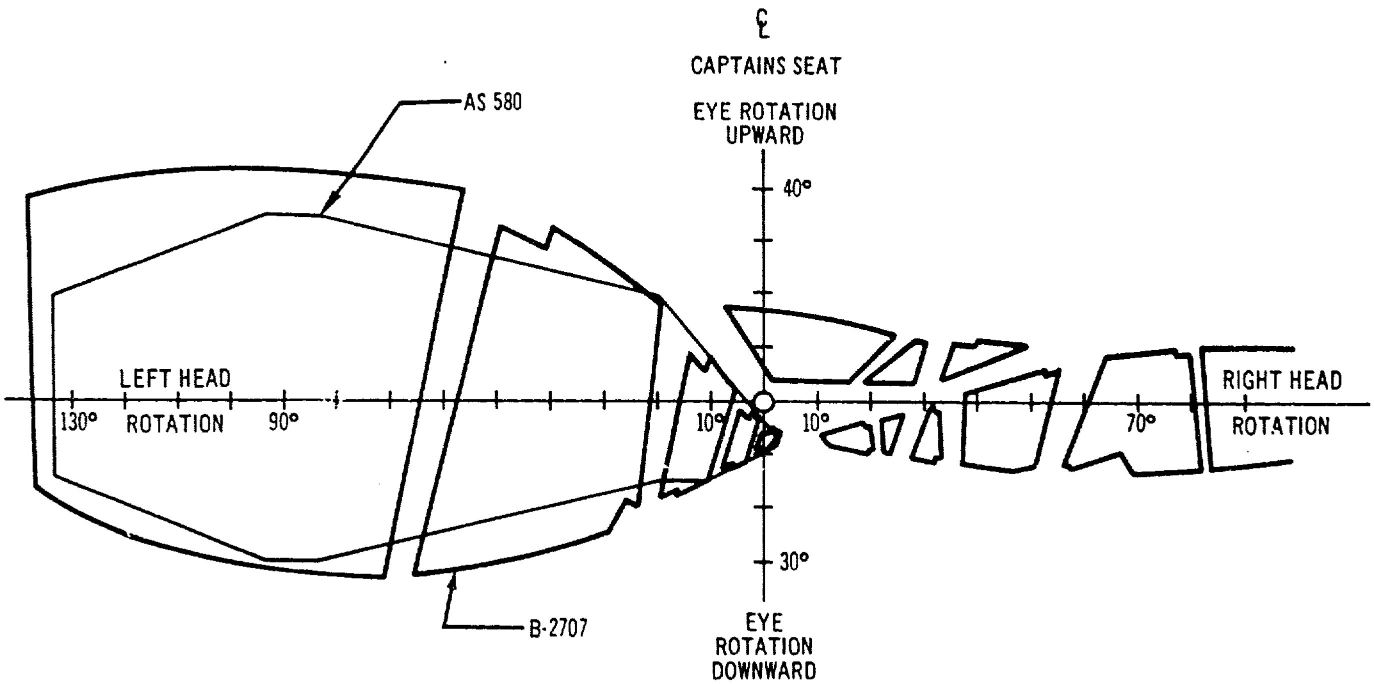


Figure 2-70. B-2707 Nose Up Vision Polar

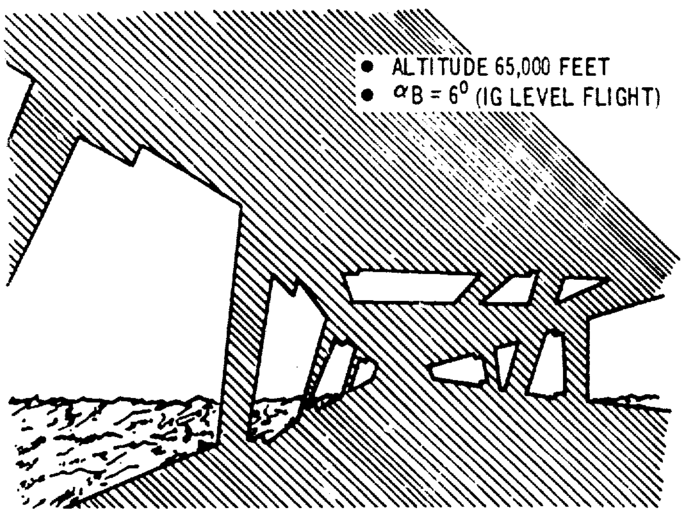


Figure 2-71. Captain' · View in Level Flight

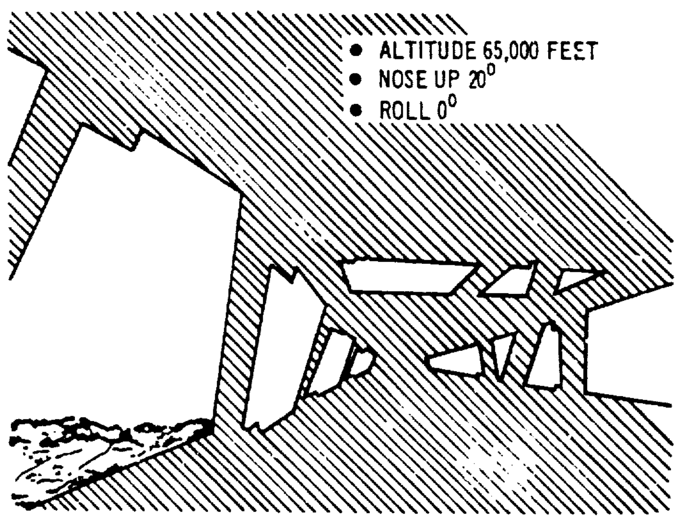


Figure 2-72. Captain's View in Level Climb

transfer. For additional discussion refer to the Flight Simulation Program, V4-B2707-13 and the Human Engineering Program V4-B2707-8.

The resulting design is one which permits forward vision directly ahead, left and right, and above and below the line the line of flight. The earth horizon can be seen at cruise attitude and altitude throughout. Adequate field of vision, to satisfy the most extreme conditions of the proposed revisions to SAE AS 530, is provided for attitude reference in the event it may be needed to permit successful recovery from an upset condition. The windows will permit observation of cloud forma-

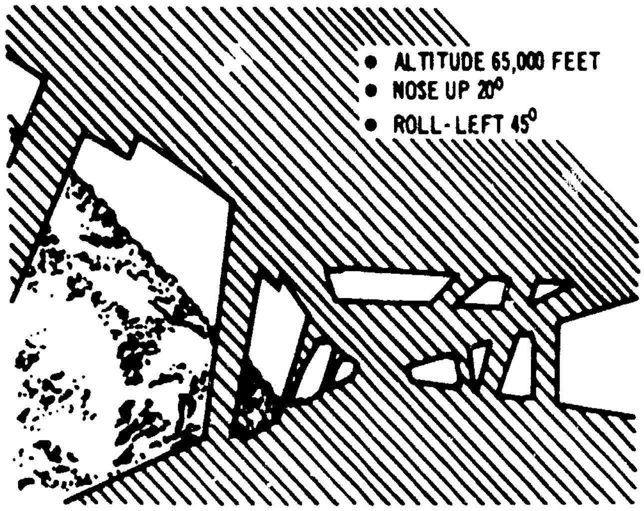


Figure 2-73. Captain's View in Climbing Turn to Left

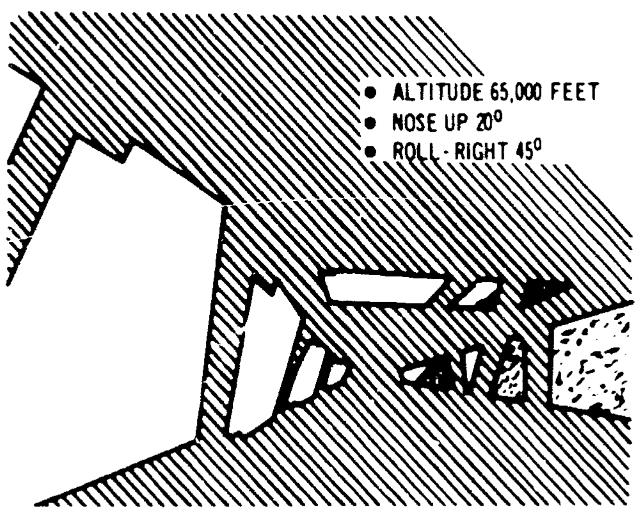


Figure 2-74. Captain's View in Climbing Turn to the Right

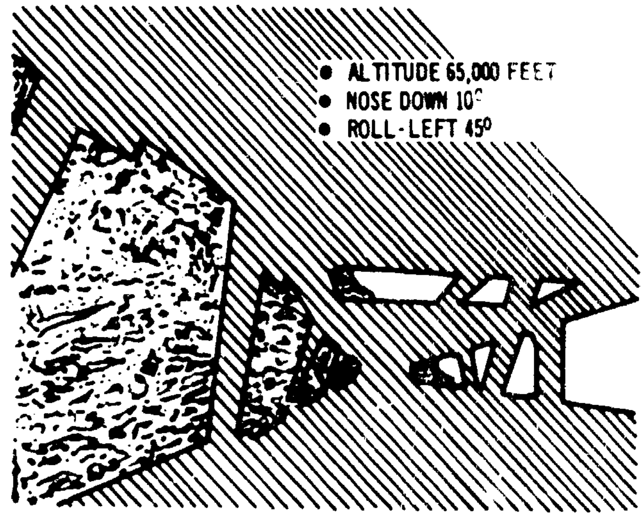


Figure 2-75. Captain's View in Descending Turn to Left

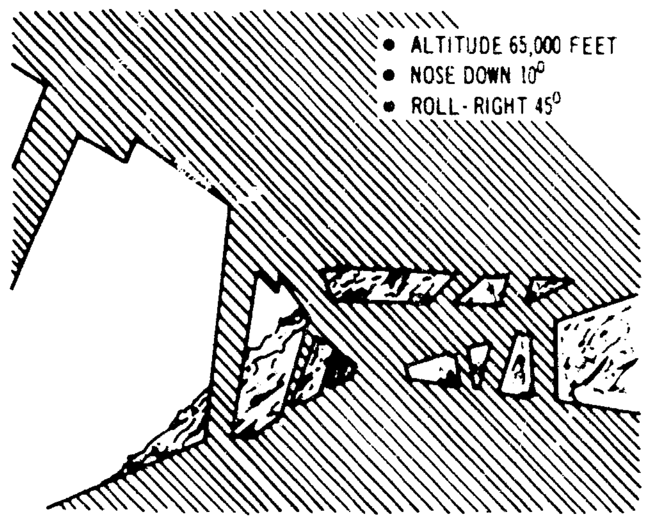


Figure 2-76. Captain's View in Descending Turn to the Right

tions and other airplanes, providing relative speeds are within the limits of human detection.

2.11.2 Subsonic Visibility
At speeds below 0.9 Mach and 395 knots CAS, the selection of any forebody position between full up and full down will be the captain's choice. The supersonic configuration will be used during transonic and supersonic flight, and it is expected that the captain will employ this configuration during the time of flight when all air traffic is under ATC control, such as in the positive control area above FL 240 over the continental U. S., or during conditions when all flight is restricted to IFR.

The forebody position is selected by means of an appropriately shaped lever on the captain's side of the center pilot's panel. The two normal positions of up and down, and intermediate positions may be used during subsonic flight, as desired. The forebody operation is by a normal and an alternate electric motor driven ball screw (Ref. Training and Training Equipment Program, V2-B2707-7). The design also provides for free fall lowering of the nose in the event of failure of the dual power system.

Subsonic visibility requirements are defined by FAR 25, including the Tentative Airworthiness Standards for Supersonic Transports, and by the

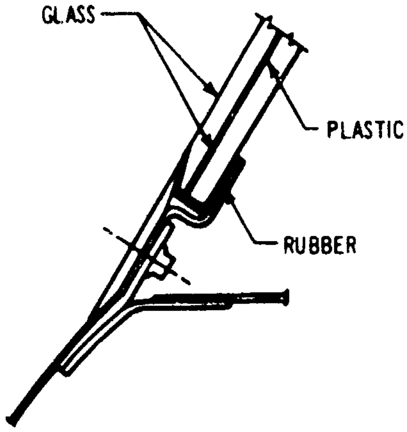


Figure 2-77. Forebody Window Lower Sill

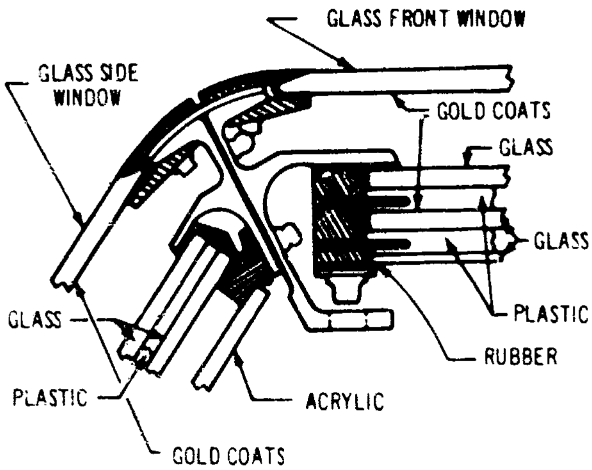


Figure 2-78. Fixed Windshield and Post

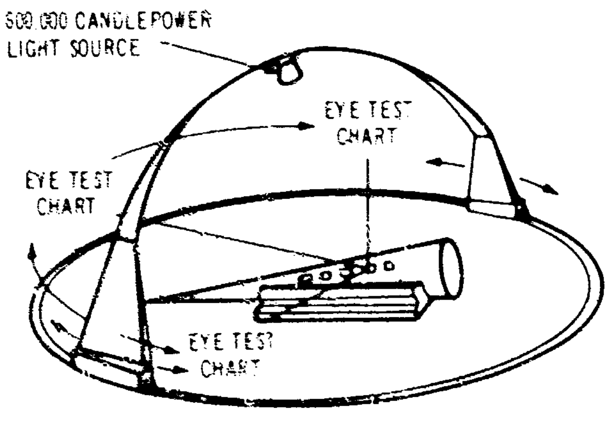


Figure 2-79. Optical Test Lab

Proposed Revision A to the Society of Automotive Engineers Aerospace Standard 580. The B-2707 design complies with all of these criteria, including the most critical requirements for vision during landing approach. The proposed revisions to SAE AS 580 are the most definitive in this respect, and currently include two proposals. The first states that: "with the airplane on a 2-1/2 deg glide slope, with its wheels at 100-ft altitude, in landing configuration at maximum landing weight, under 1,200 ft RVR conditions and zero to maximum crosswind yaw, the forward and down visibility angle, as measured from a horizontal plane through the design flight eye position, and in a vertical plane coincident with the flight path to account for yaw, shall permit the pilot to observe a horizontal distance fore and aft on the surface of the ground equivalent to the distance travelled in three seconds at approach speed." The second proposal requires that under the same conditions the pilot should be able to see either the threshold or wing bar approach lights plus three other approach light bars from a 2-1/2-deg and a 3-deg glide slope. Since the first proposal is the more demanding and represents the standards provided in current jet transports, it has been used as the design criterion.

Figure 2-80 shows the landing flap setting, attitude, and speed trades for a normal landing condition. The design point for down vision is based on an approach speed of 135 knots with flaps fully extended. More down vision results from increasing the approach speed, such as would be the case in crosswinds or turbulence, and approach noise can be reduced by using a lower flap setting and more speed. It is noted that at the 135-knot design point, the B-2707 approach noise is approximately 1/4 the intensity of that from current jet transports.

Figures 2-81 and 2-82 show, for comparison, the approach down vision geometry of the B-2707 and the 707-320C. The B-2707 compliance with the criteria is slightly superior to that of the 707-320C.

Figure 2-83 shows the subsonic vision envelope in comparison with the SAE AS 580 criterion. It is noted that the B-2707 field of vision is substantially greater through all windows than is required by the criterion. The field of view through the forward windows is shifted downwards 3 deg to compensate for the 6-deg nose down seating plane

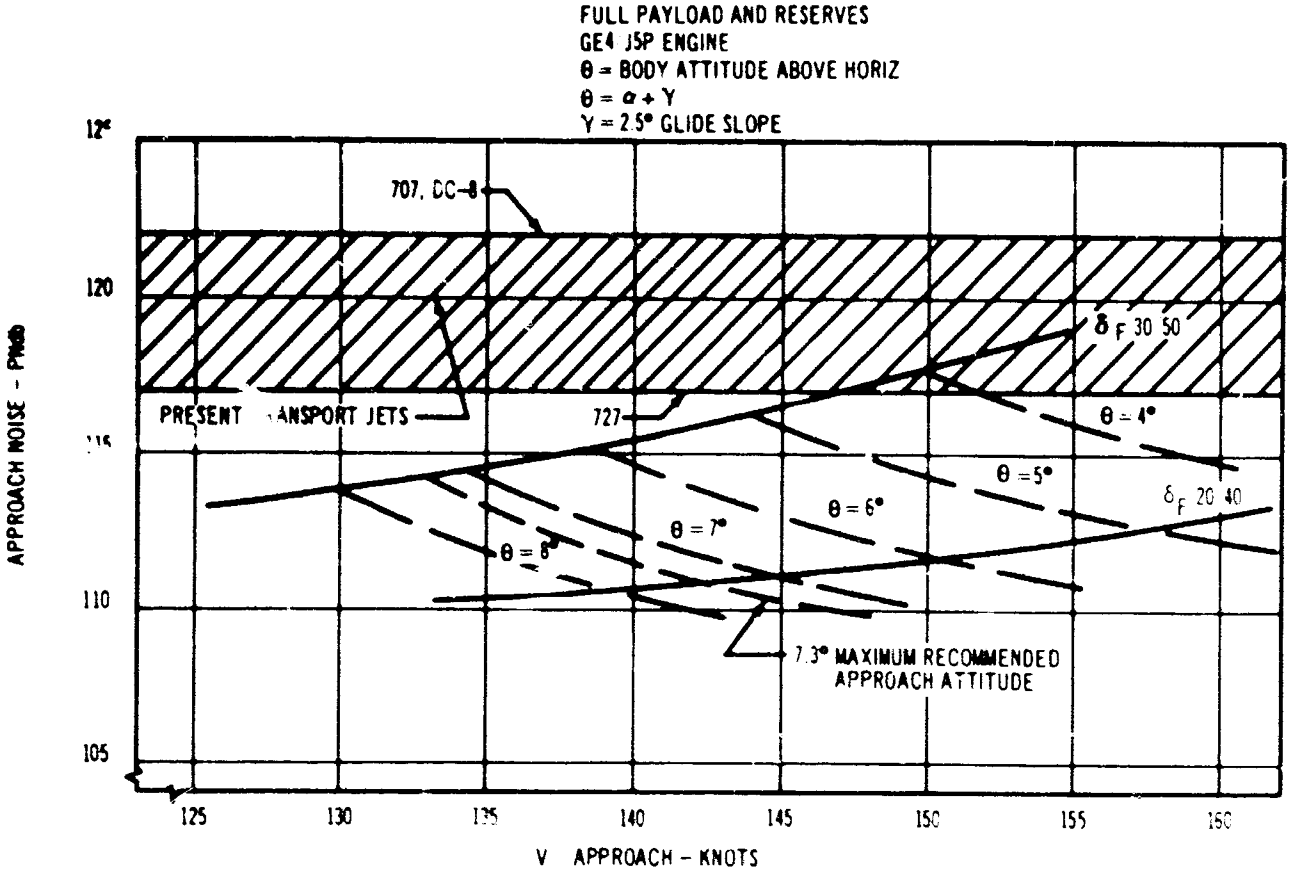


Figure 2-80. Typical Approach Noise -- Velocity Trades

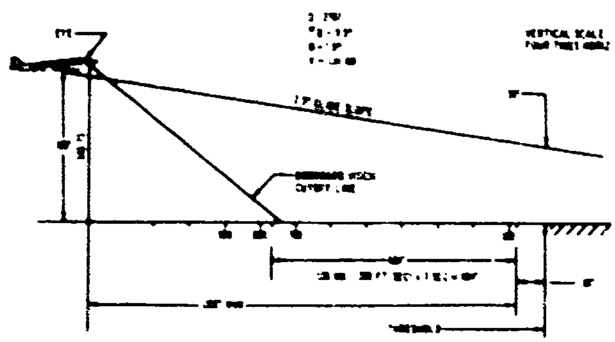


Figure 2-81. B-2707 Approach Vision

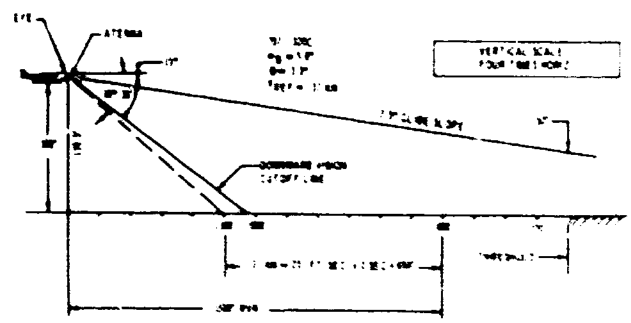


Figure 2-82 707 Approach Vision

of the pilot, relative to the fuselage datum. Relative to their seating plane, the pilots will have 23 deg of up and 16 deg of down vision.

Figure 2-84 illustrates the captain's visibility when on approach with his wheels at 100-ft altitude. The first officer's visibility is identical but of opposite hand.

Simulator studies, have shown that landing can be safely executed with the visibility available in the nose up position, in the unlikely event of dual mechanization failure and failure of the free fall system. Such an approach and landing would be performed with use of the glide slope and localizer facilities and by increasing the speed by

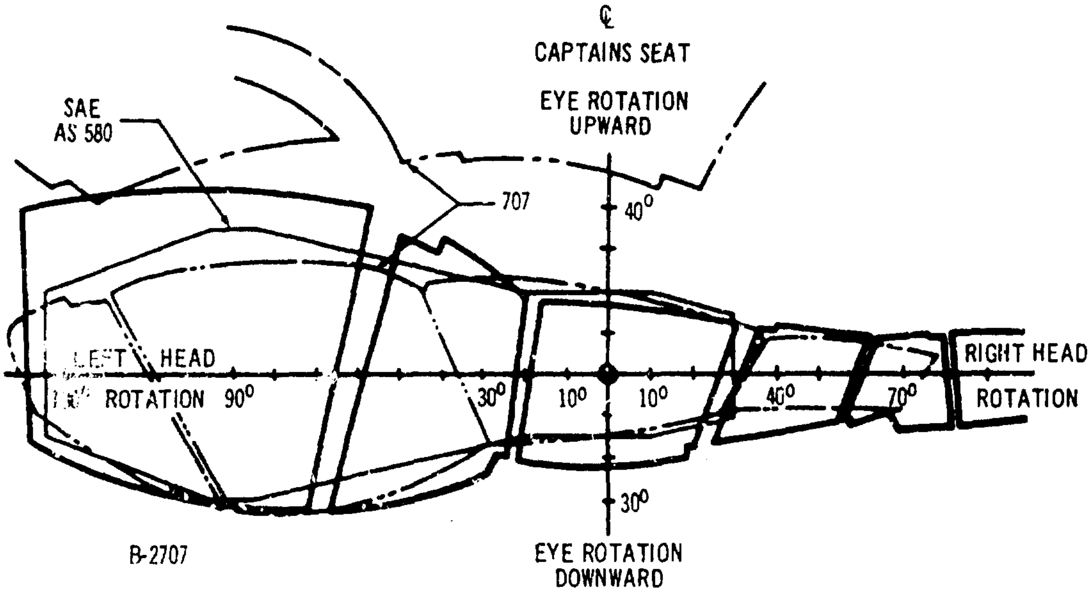


Figure 2-83. B-2707 Nose Down Vision Polar

approximately 13 knots to achieve the best vision (Fig. 2-85).

Figure 2-86 shows a comparison of B-2707 and 707 taxi vision. Forward vision is superior to that of the 707, but side vision is not quite as good because of the greater height of the eye position above the runway.

2.11.3 Rain and Fog Provisions

Windshield wipers and rain repellent are used for rain removal on the two forward fixed windows. Anti-icing is provided through electrical heating of the outer panes of these same windows. Fogging does not occur because of the insulation characteristics of the coated multi-layer glass panes and air spaces. On the two forward fixed windows, heating is applied to the bird-proofing interlayer material to maintain maximum energy absorption elasticity. This heat will also act as a fog preventative. Test Integration and Management, V4-B2707-10, Sec. 1.0, describes the rain removal, anti-icing, and defogging systems.

The forebody side windows are provided with an anti-fog protection system. Rain removal and anti-icing provisions are not required for normal operations. It was the consensus of the airline team representatives that these should not be provided for abnormal operations.

2.11.4 Pilot Vision Supplement

Laboratory studies on the use of closed circuit TV as a pilot vision supplement were started in December 1965 (Ref. 4) and in 1966, inflight tests were made in a 707 (Ref. 5). A typical TV picture is shown on Fig. 2-87. Operation modes which have high potential are taxiing, approach and landing, inflight viewing of equipment and external airframe surveillance.

The Boeing SST project pilot conducted the tests of Ref. 5 and he is confident that landings can be safely accomplished with vision information supplied by TV, providing attitude and altitude references are superimposed on the display. In addition to augmenting windshield vision, a TV camera located on the lower fuselage will provide an image of the approach lights when visibility conditions preclude this for the naked eye because of windshield geometric down vision cutoff angle limitations. Because of the promise of combining a TV picture of the real world with typical attitude director information, laboratory development work of an installation for 707 tests is in progress. Results from cruise vision tests have shown inadequate picture contrast and resolution; however, it is expected that advanced secondary emission conduction (SEC) TV equipment will show considerable improvement over the vidicon used in the experiments.

The prototype will be fitted with a TV installation for evaluation of the requirement for vision augmentation during ground maneuvering. This installation will also provide for further evaluation

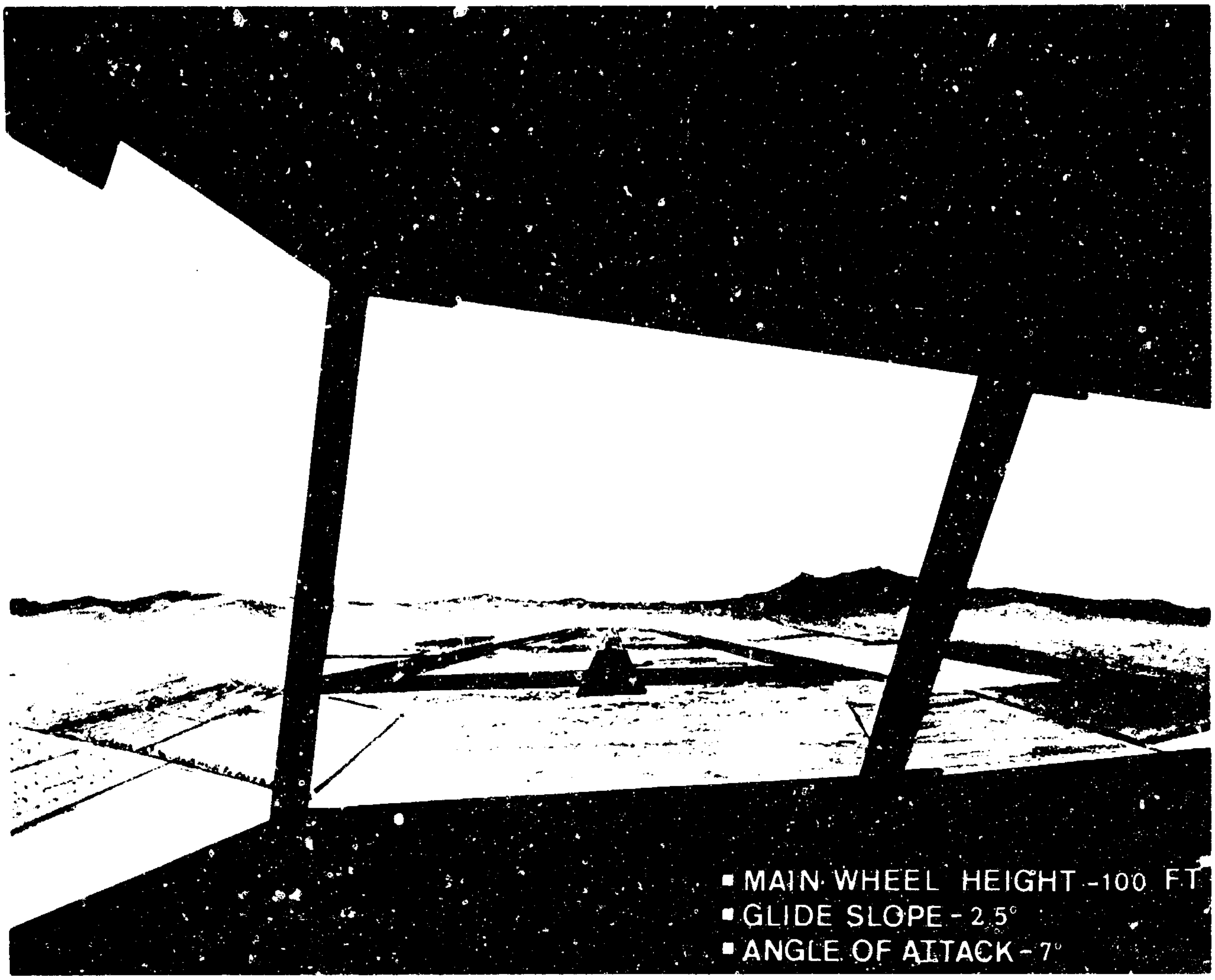


Figure 2-84. Captain's View on Approach

of its usefulness for vision augmentation during cruise flight and landing approach.

2.11.5 Abnormal Operation

a. Nose Mechanism Failure in the Up Position

Simulator studies have demonstrated that landings can be safely completed with the nose locked up. The runway is visible at 100 ft altitude through the forward nose window, as shown in Fig. 2-85, at an approach angle of attack of 7 deg, which corresponds to an approach speed of 148 knots with full payload and reserves. As the airplane approaches for the flare, the edges of the runway appear successively in the window areas from the front to the side. The possibility of using this capability is extremely remote because of the provision of a dual power source and free-fall capability for lowering the nose.

b. Landing with the Wings Aft

Landings with the wings at 72 deg will require three to four degrees more nose up body attitude than normal, and therefore the horizontal surface visible in front of the nose will be reduced by 250 ft. Under VFR landing conditions this will not present a problem. The visibility will also be adequate for the least demanding of the two proposed revisions to SAE AS 580 for Category II landing conditions, as noted in Par. 2.11.2.

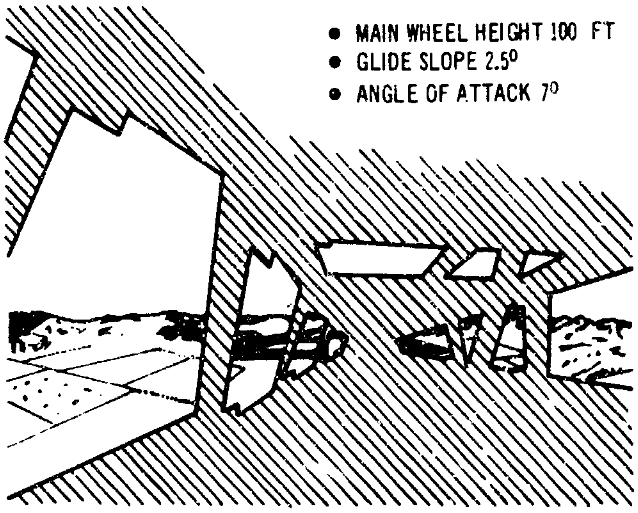


Figure 2-85. Captain's View in Nose Locked up Approach

c. Windshield Glass Failure

See System Safety Plan, V4-B2707-6 for details of the effects of windshield glass failure.

d. Rain Removal System Failures

The rain removal system employs both a wiper system and a rain repellent system. The wiper system is required for taxi operations where there is insufficient aerodynamic flow over the windows to permit the repellent system to work. The repellent system is adequate for all flight situations.

Failure of a wiper system will cause the associated window to be without rain removal during ground taxi. This is not considered to be hazardous.

There are two rain repellent systems, one for the captain's window and one for the first officer's window. A crossfeed feature provides for the event of failure of one supply system by routing fluid from the operative system. In the unlikely event of failure of both systems the windshield wipers may be used.

e. Anti-icing Failure

Anti-icing is provided for the captain's and first officer's front windshields. In the event of failure of one system the other pilot would assume visual responsibilities. The ice could be removed from the failed system side by increasing the subsonic speed to increase kinetic heating if the airplane flight plan precluded the use of altitudes where temperatures above freezing prevailed.

f. Defogging

Defogging provisions are provided on the six nose windows to remove fog which can result during climb. In the event of failure of a system the visibility through the affected window would be temporarily lost until the glass was sufficiently heated by kinetic heating to cause its removal or until frost, which might form as a result of sustained low speed high altitude flight, had sublimated.

2.12 CREW WORKLOAD ANALYSIS

The objective of the analysis was to determine flight crew workload during a normal flight profile and to identify mission segments or operation which create an excessive demand on the crew or crew member. A secondary objective was to compile an integrated, serial description of crew tasks to cover all systems and/or subsystems controlled, used, or monitored by the flight deck crew.

2.12.1 Flight Deck Provisions

The flight deck provides accommodations for a three-man crew and two observers. Figure 2-88 shows the flight deck crew and observer stations. Commercial airline practice has been followed throughout the analysis in designating the crew as captain, first officer, and flight engineer.

2.12.2 Flight Profile and Mission Segments

An examination of the functional flow diagrams (Ref. 6) resulted in the selection of Function 1.3, Transport Payload, as the most representative function which could be examined in detail on a timely basis. This function covers all flight crew functions from engine start through supersonic cruise phase to postflight engine shut-down. One operation unique to the B-2707, inertial navigation checkpoint insertion, has been included within the engine start analysis because it is performed onboard by a flight crew member and must precede start-up even though the operation is unrelated to starting engines. Flight profile mission segments parallel the sub-functions of Ref. 6 because of clear cut lines of demarcation between them.

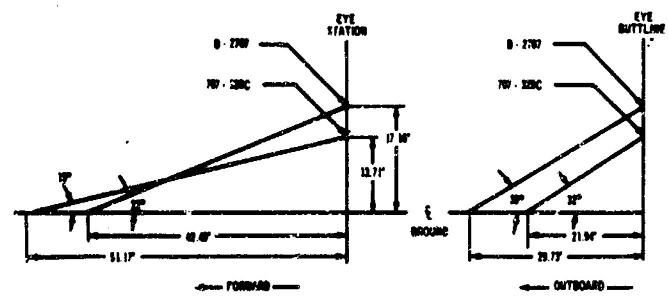


Figure 2-86. B-2707 and 707 Taxi Vision

Those selected for analysis are as follows:

- Engine start
- Taxi and takoff
- Climb
- Cruise
- Descent
- Land
- Taxi and Park (including shutdown)

A generalized supersonic flight profile was used in preparing the workload analysis. Detailed profile descriptions are presented in Airplane Performance, V2-B2707-4 and -5.

2.12.3 Work Load Development and Ground Rules
To determine crew workload, a detailed task analysis on a real-time basis was performed. Each mission segment was broken down into essential operations consisting of a number of tasks or sub-tasks. The level of detail was extended to every known or deduced movement of controls, levers, knobs, reading of instruments, radio or voice communications performed by the flight crew. Each of these tasks was assigned an estimated performance time in increments of one second or more. The outline of operations and tasks was based on a similar study of commercial jet airline operations. Details of unique operations were conducted in parallel with systems and subsystem development. Information to fill procedural gaps was derived by examination of control layouts and display panels.

The flight profile was assumed to be a continuation flight and as such the Inertial Navigation (I-NAV) gyros would require a minimum warmup. The flight would be flown on autopilot in the AUTO NAV mode with the stability augmentation, auto-throttle, and I-NAV systems engaged from the earliest moment of the climb segment. The airplane would be shifted to MANUAL autopilot mode for the descent phase and a fully manual landing conducted while under visual flight rules. Three timeline charts summarizing the task analysis data were prepared (Figs. 2-89 through 2-91). Each of the seven mission segments of Function 1.3, Transport Payload, is plotted in serial order. Each operation within a segment is listed serially followed by a bar representing the estimated real-time required by the flight crew or crew member to perform the operation. When concurrent operations occur, the time bars overlap. During the climb, cruise, and descent segments where tasks are largely repetitive and the times extensive, the time bars are broken to save space and avoid unnecessary duplication. A work load summary at the bottom of Figs. 2-89 through 2-91, represents that proportion of each crew member's time required to perform his tasks. In addition, whenever the airplane is in motion, each crew member is assumed to be worked to 50 percent of capacity with routine instrument monitoring, adjustments, scanning for other traffic, intra and extra airplane communications, etc. The cross-hatched portions of the workload summary represent periods when the pilot and co-pilot are dependent upon visual reference wholly or in part to control the airplane. For example, external ground checks of flight controls, taxi operations, takeoff, and climb-out until instrument flight operations could be employed are cross-hatched functions. All other functions are shown as solid black bars.

2.12.4 Crew Workload Study Conclusions
In summary, no critically high crew work loads are apparent. Marginal workload areas occur when manual functions predominate because of the time compression of supersonic flight operations. Where automation is used, the problem of marginal performance disappears. As system definition progresses and more comprehensive simulation data becomes available, the crew workloads will be re-evaluated, especially those now indicating marginal performance.

The preliminary investigation shows no problems during normal flight. However, emergency conditions may tax the information assimilation reaction capability of the flight crew. Detailed task analyses of emergency flight operations will be conducted during Phase III. Other situations relative to normal operations and unique to super-

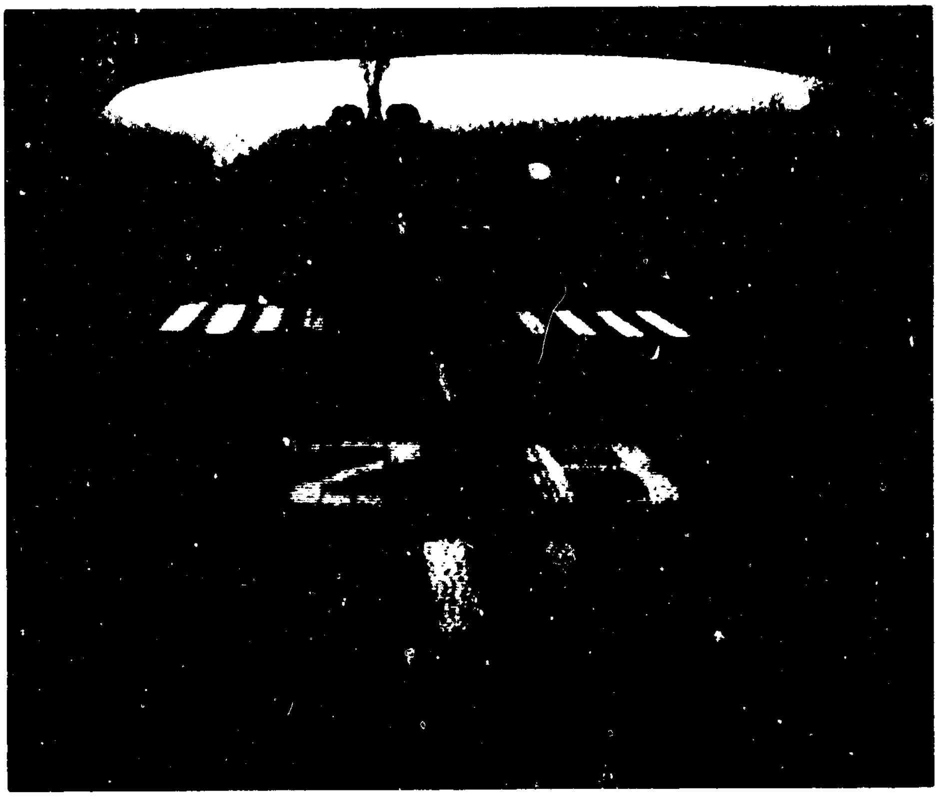


Figure 2-87. Televised View of 707 Landing Gear

sonic flight may be discovered during simulation studies and more detailed analysis.

In addition, activities which were found to be time consuming will be further studied in Phase III.

The I-NAV system gyro warmup time must be considered in programming airplane turnaround time. The insertion of I-NAV checkpoint data is time consuming and at least the first checkpoint must be inserted before engine start. Each checkpoint inserted will require approximately 65 seconds of complete attention by a crew member. This crew member must be on board the airplane sooner than required for present jets. Additional checkpoints (up to 7) could be inserted while enroute.

Additional study is required to determine the extent to which VOR or conventional ADP navigation systems load crew functions and to determine the most efficient and practical balance between these conventional navigation aids and the inertial navigation systems.

During Phase III, preflight and postflight crew activities will be added to the task analysis. Studies will be made to define system checklist requirements and procedures, with particular attention given to ensuring their compatibility with operational time constraints.

2.13 DISPATCH AND FLIGHT WITH INOPERATIVE UNITS

2.13.1 Minimum Equipment List

FAR 121.627(c) permits the publication of a minimum equipment list (MEL) designed to provide operators with the authority to operate an airplane with certain items or components inoperative provided an acceptable level of safety is maintained by appropriate operating limitations, by a transfer of the function to another operating component, or by reference to other instruments or components providing the required information. The MEL does not include obviously required equipment such as structure, nor does it include items which obviously do not affect airworthiness, such as passenger service and entertainment items.

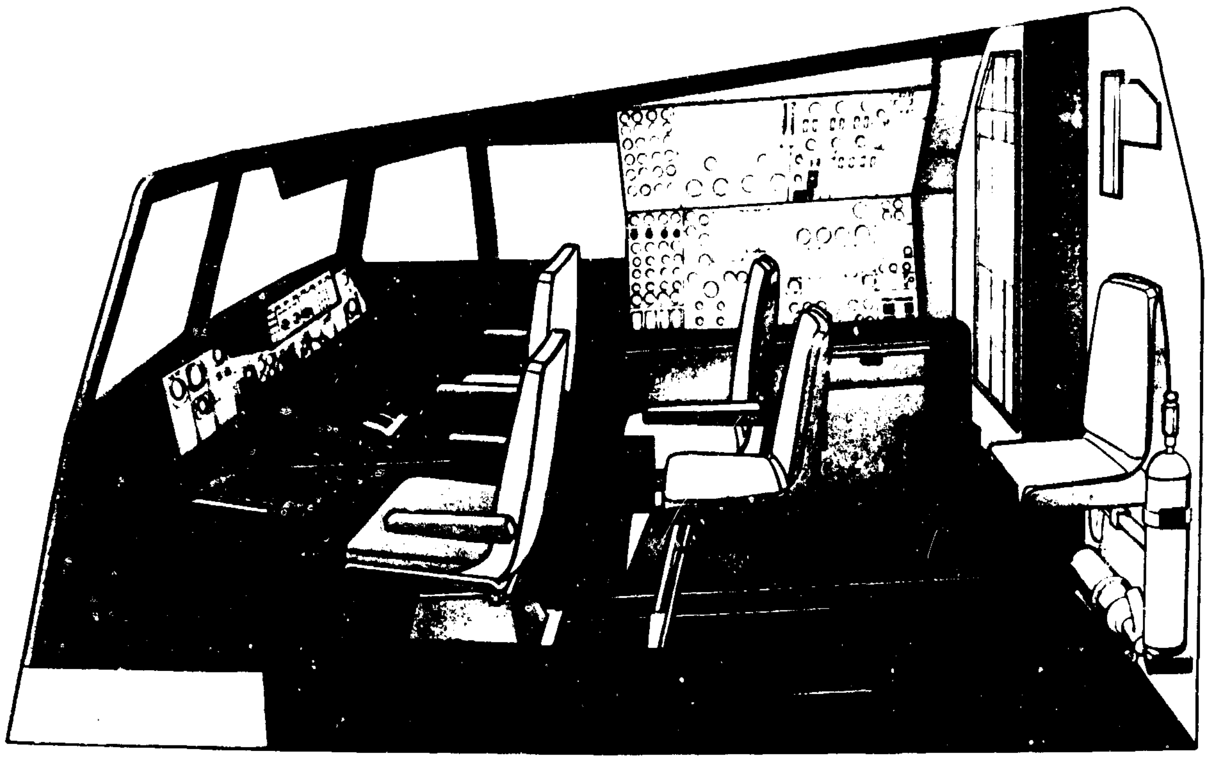


Figure 2-88. General Flight Deck Arrangement

A tentative MEL has been prepared for the B-2707 with operating limitations noted and is available for on-site review. Figure 2-92 presents a page from the tentative MEL. The final MEL will be negotiated among FAA, the participating airlines, and The Boeing Company.

2.13.2 Preliminary Operational Equipment Tabulation

A Preliminary Operational Equipment Tabulation has been derived to indicate the capability of the airplane to continue flight operation with equipment inoperative. This list is used for analyzing reliability, safety, and related factors of the B-2707 airplane.

This list has been tabulated to show equipment requirements for continued subsonic or supersonic operation over land and water at high and low altitude. These equipment considerations are probably more stringent than would be encountered in actual use and, therefore, present a conservative evaluation of the ability of the B-2707 to operate successfully in airline operation.

Because of the extensive nature of this tabulation, only one page is shown in Fig. 2-93. The entire tabulation is available for on-site review.

2.14 GROUND ENVIRONMENT FLEXIBILITY

The B-2707 is adaptable to the various ground operations and conditions in which it will operate. This adaptability is the result of studies and analysis of airline operations, investigations of airport suitability and experience gained in successfully deploying subsonic jet transports with many of the world's airlines.

The B-2707 can land at the airports which accommodate present large jet transports, such as the 707 and DC-8. In the normal landing configuration, the wings swept forward and flaps extended, the B-2707 approach and landing speed is equivalent to or less than present large jet transports.

The B-2707 airplane has pavement depth requirements equal to or less than existing jet aircraft. This is accomplished by a four wheel four truck main landing gear which applies four loading

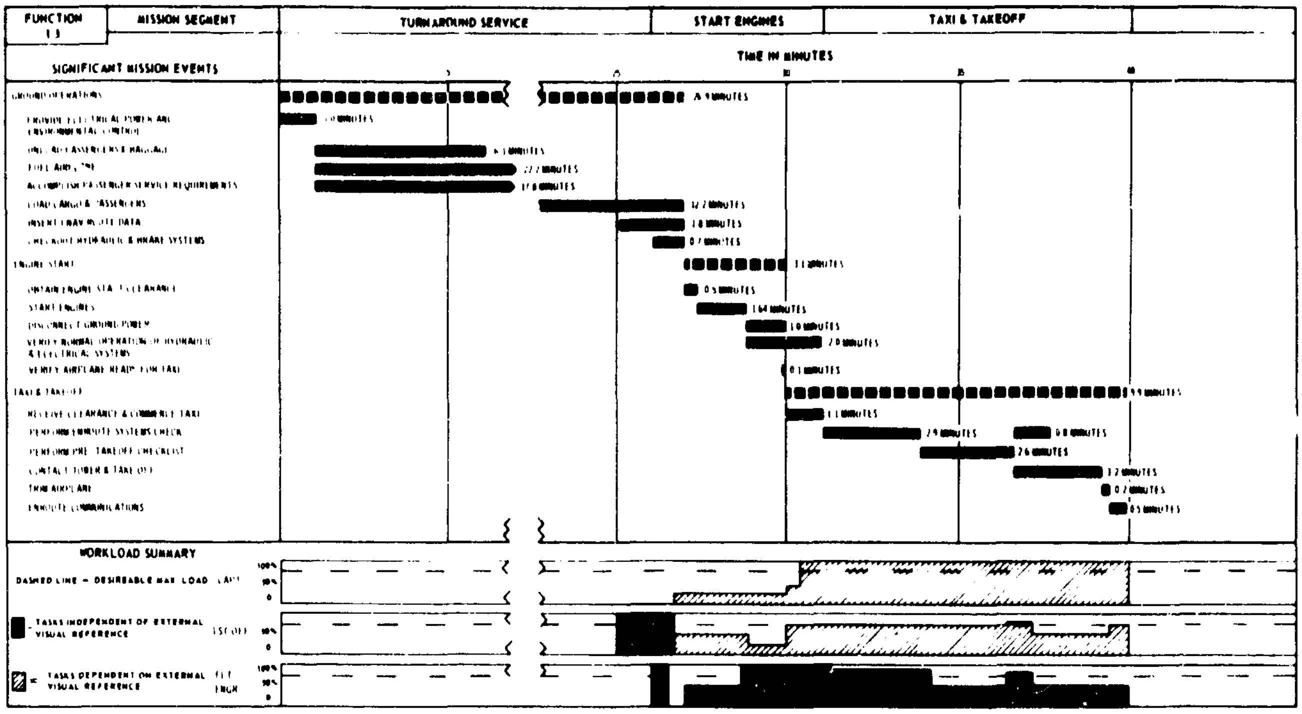


Figure 2-89. Timeline No. 1

groups to the pavement, each essentially the same as the loading groups on the DC-8-55 (used as the baseline objective). Section 4.0 of this document shows the B-2707 to have an excellent degree of compatibility with respect to its effect upon the pavement complexes of 15 international airports in the United States.

The 16 main landing gear wheels are equipped with brakes sized to provide the pilot with adequate ground control of the airplane during all taxi conditions. The brakes are controlled from the rudder pedals and are used to aid the airplane in turning as well as braking.

Landing the B-2707 on rough runways will have minimum effect on the airplane and the comfort of the passengers. The landing gears have compression strokes and compression ratios which will provide a soft touchdown and will absorb the shock of rough runways during the landing rollout and taxi operations. For the analysis of B-2707 operation on rough runways see the Airframe Design Report, Part B, V2-B2707-7.

The B-2707 extended flaps prevent ingestion of foreign objects which may be thrown up by the main landing gear wheels during takeoff, landing, or taxi operations (Fig. 2-94).

Throughout the ground operations, flight crew visibility is equivalent to that of current jet transports. With the nose tilted, the B-2707 clears objects, such as snow banks and fences, 48 in. high. Additional clearance is attained by raising the tilt nose which has a response time of 15 seconds from full down to the full up position. Intermediate positions are also available. Steering capability on the rear main landing gears as well as the nose gear permits the B-2707 to maneuver on the ground with maximum ease. The pilot will have no difficulty in maneuvering the B-2707 onto or off the runways and steering the airplane into a parallel, canted or nose in parking position. A TV display of the airplane undercarriage for aiding ground maneuvering, is provided on the prototype airplane. This display will be evaluated during Phase III to determine its effectiveness for airline operations.

The B-2707 is equipped with an accessory drive system, which is shaft-driven from the engines, when running, and may be driven by the ground air start turbine on the ground. This feature permits the ADS to be used on the ground as an optional means of supplying ground electrical and hydraulic power. A high pressure ground air supply is used to drive the air start turbine, and

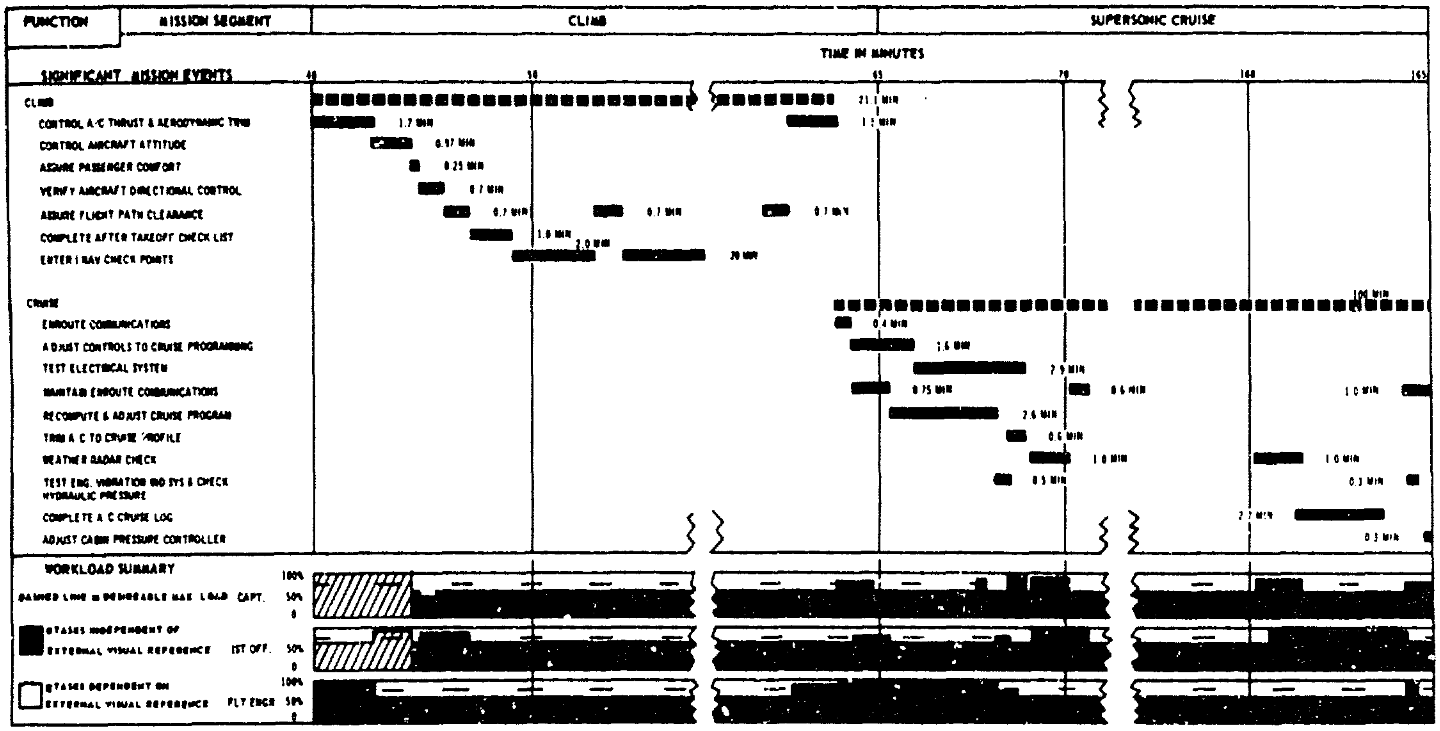


Figure 2–90. Timeline No. 2

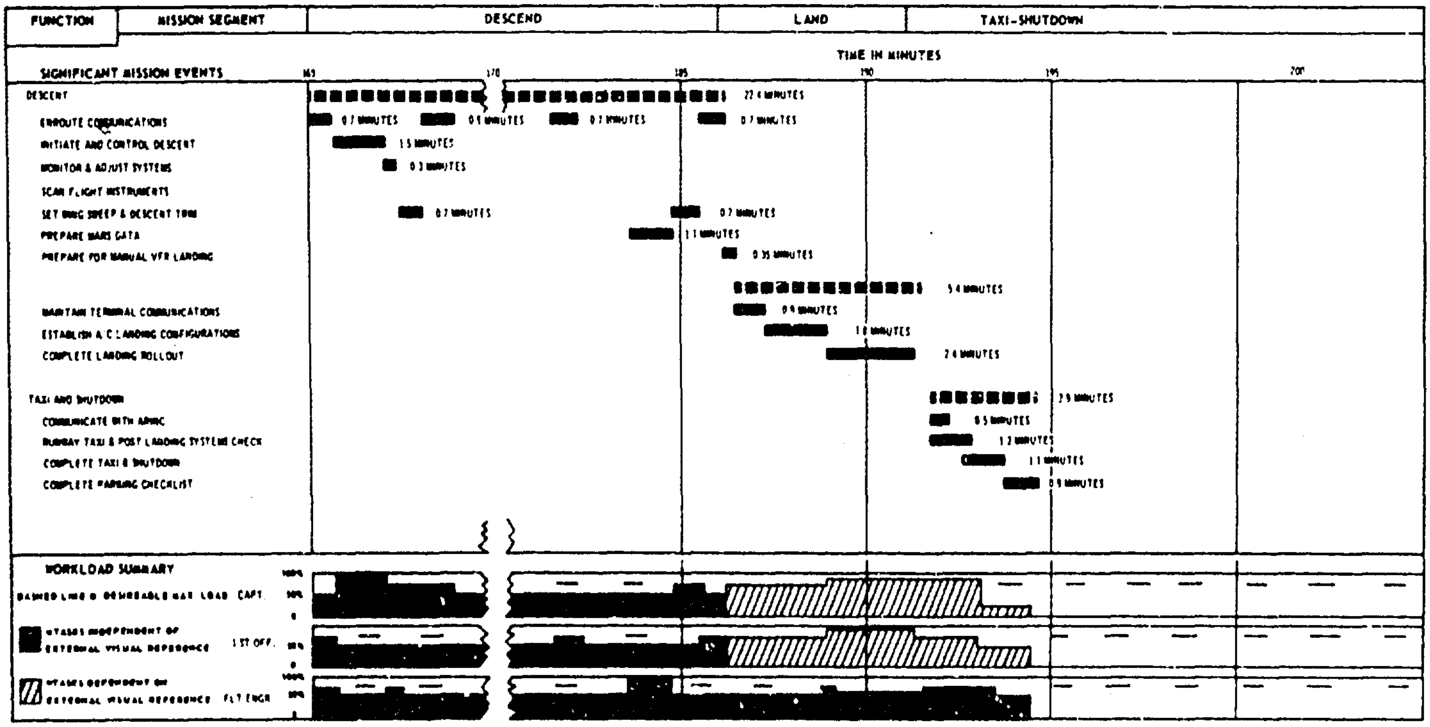


Figure 2–91. Timeline No. 3

TENTATIVE MINIMUM EQUIPMENT LIST			
AIRCRAFT: B 2707		REVISION NO. DATE: 7-29-66	PAGE 24-1
SYSTEM & SEQUENCE NUMBERS	ITEM	1. REQUIRED FOR DISPATCH OF ALL FLIGHT CONDITIONS EXCEPT AS PROVIDED IN COLUMN 2	2. REMARKS AND/OR EXCEPTIONS
24	ELECTRICAL POWER		
-1	Generator	4	One generator may be inoperative provided electrical loads are monitored.
-2	Generator Temperature Indicator	-	One for each operating generator
-3	Generator Automatic Paralleling System	1	May be inoperative but manual paralleling procedure must be followed if generators are to be operated in parallel.
-4	Transformer Rectifier	6	Nos. 1, 2, 3, or 4 T-R's may be inoperative. One essential T-R must be operative at all times.
-5	Frequency Light	-	One for each operating generator.
-6	DC Voltmeter	1	
-7	DC Ammeter	1	
-8	Battery	1	
-9	Generator System Annunciator Panel	0	
-10	Standby Static Inverter	0	
-11	External Power (ground) System	0	

Figure 2-92. Tentative Minimum Equipment List

SEQUENCE NUMBER	ITEM	QUANTITY PER AIRPLANE	QUANTITY REQUIRED TO CONDITION FLIGHT								REMARKS AND OR EXCEPTIONS*
			SUBSONIC								
			OVER LAND		OVER WATER		OVER LAND		OVER WATER		
24	ELECTRICAL POWER		HI ALT	LO ALT	HI ALT	LO ALT	HI ALT	LO ALT	HI ALT	LO ALT	
24-1	A.C. GENERATION CHANNEL	4	1	1	1	1	2	2	2	2	
24-2	GENERATOR MALFUNCTION INDICATOR	4	1	←	→	←	→	←	→	1	1 MAY BE INOPERATIVE PROVIDED ALL OTHER GENERATOR FUNCTIONS AND INDICATORS ARE OPERATIVE
24-3	GENERATOR TEMPERATURE INDICATING SYSTEM	4	2	←	→	←	→	←	→	2	2 MAY BE INOPERATIVE PROVIDED THE CORRESPONDING AMMETER IS FUNCTIONING NORMALLY AND THE GENERATOR MALFUNCTION INDICATOR FUNCTIONS NORMALLY
24-4	A.C. AMMETER	4	3	←	→	←	→	←	→	3	3 TWO A.C. AMMETERS MAY BE INOPERATIVE PROVIDED THE CORRESPONDING GENERATOR TEMPERATURE INDICATING SYSTEM IS FUNCTIONING PROPERLY
24-5	MULTI-METER (A.C. - D.C.)	1	4	←	→	←	→	←	→	4	4 MAY BE INOPERATIVE PROVIDED ALL OTHER GENERATOR FUNCTIONS AND INDICATORS OPERATE
24-6	STANDBY SYSTEM	1	1	1	1	1	1	1	1	1	
24-7	D.C. AMMETER	1	1	1	1		1	1	1	1	
24-8	TRANSFORMER RECTIFIER	6	3	3	3	3	3	3	3	3	
24-9	EXTERNAL POWER (GROUND)	2	0	0	0	0	0	0	0	0	
24-10	AUTOMATIC GENERATOR PARALLELING SYSTEM	5	5	←	→	←	→	←	→	5	5 [illegible] DISPATCH - SPLIT PARALLEL [illegible] CONTINUED FLIGHT - NOT REQUIRED

* FERRY FLIGHT - NO CHANGES FROM [illegible] EQUIPMENT REQUIREMENTS OF REGULARLY SCHEDULED FLIGHTS FOR ANY ELECTRICAL POWER ITEM LISTED 24-1 THROUGH 24-10

Figure 2-93. Preliminary Operational Equipment Tabulation

the ADS transmits shaft power to the hydraulic pumps and electric power generator.

The high pressure ground air supply which is used to drive the air start turbine for ADS operations as well as for engine starts, may be also used to deliver air directly into the environmental control system to provide ground cooling in lieu of a low pressure ground air-conditioner.

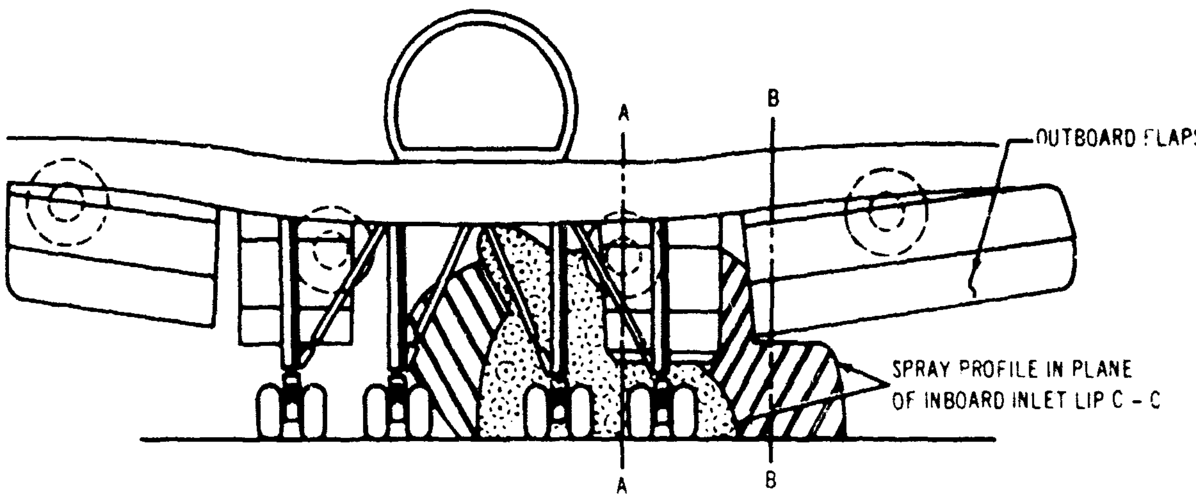
In addition to ground power provisions the B-2707 is provided with onboard standby battery power, which can be used in emergency situations to augment, or substitute for, external ground electrical power.

The B-2707 is towed by tug and tow bar attached to the nose gear. The larger tow vehicles presently in use by the airlines for use with subsonic jet aircraft are capable of towing the B-2707 on 2.0 percent grade and dry pavement conditions.

The B-2707 is designed with four passenger loading doors on the left-hand side of the airplane which will permit rapid loading and unloading of passengers. The two forward passenger loading doors will interface with present ground loading equipment, such as rollup stairways or extension jetways. The two rear passenger loading doors, if required, will require extension of current loading techniques and equipment. The B-2707 allows the airport operators and airlines, flexibility in determining and planning the most suitable utilization of passenger loading doors to fit present and planned airport facility arrangements. Using the forward 2 loading doors, 277 passengers can be loaded in 9-1/2 minutes or unloaded in 8 minutes.

In general, the B-2707 can be accommodated by using existing servicing equipment at airports equipped for subsonic jet transports; however, for most efficient service some modifications to existing equipment and some new equipment is recommended as discussed in Par. 3.7.

The B-2707 will permit loading of loose or containerized cargo at the option of the airlines. Provisions are included for: an automatic cargo loading system which will raise the cargo from the ground and traverse it to the stowed position, or interface with the ground loading equipment which raises the cargo or baggage to the cargo compartment floor level. Using the ground loader will require that the cargo or baggage be moved to the stowed position manually.



1" WATER ON RUNWAY 90 KT ROLLING SPEED

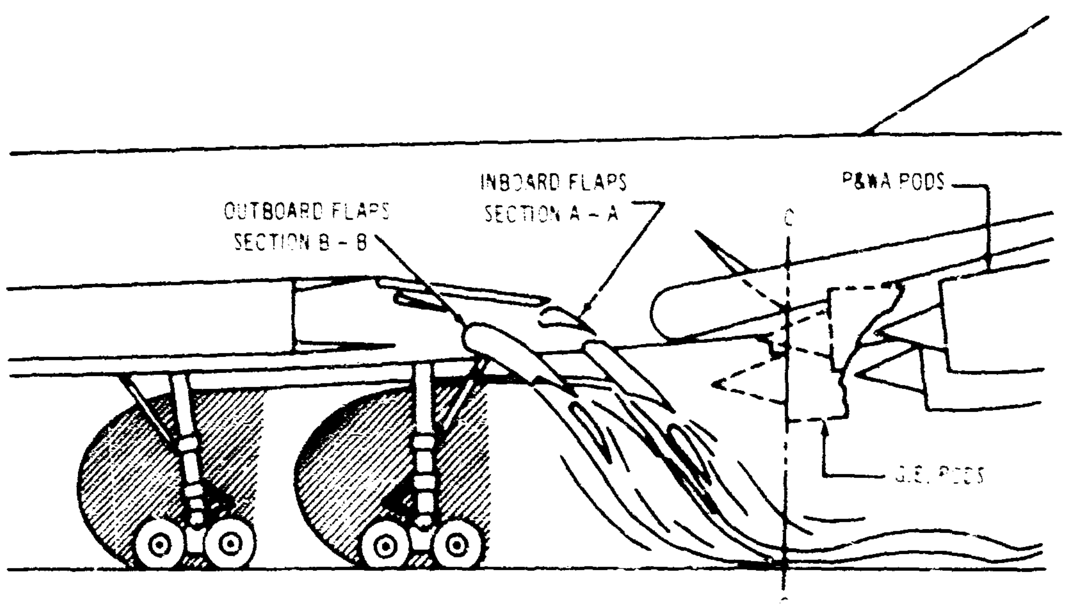


Figure 2–94. Inlet Ingestion Prevention, Water and Flush

The fuel system is designed to accept fuel from existing mobile and fixed fueling facilities through receptacles provided on both the right-hand and left-hand sides of the airplane. A fueling control panel is provided adjacent to one fuel receptacle to permit complete control and monitoring of the fueling operation from the exterior of the airplane.

In performing departure operations, the B-2707 may be moved from the loading dock under its own power or may be started in position and then moved by a towing tug.

Provisions designed into the B-2707, such as quick access to maintenance and service areas, self-test features, and replaceable modules will facilitate both maintenance and ground operations.

The design and maintenance planning for the B-2707 stresses features for improved condition visibility for all elements, so that the "on condition" maintenance concept and the extended service life established for the airplane and its equipment can be achieved. Condition visibility, critical item redundancy, deferred maintenance capability along with the scheduled inspection cycle programmed will allow the B-2707 to operate in the subsonic jet ground environment.

CONTENTS

3.0 ENVIRONMENT INTEGRATION

3.1 INTRODUCTION

This section reports the results of studies and analyses performed during Phase II-C on turbulence, ozone content, radiation, particulate matter, air traffic control (ATC), navigation, communications, ground servicing, ground handling, and maintenance. The results of these studies and analyses are reflected in the design of the B-2707 and ground support equipment. More detailed information on these subjects can be found in other volumes of the Phase III proposal. Reference will be made to these volumes where appropriate.

3.2 TURBULENCE

3.2.1 Improved Capability

An improved operational capability with respect to avoidance and penetration of moderate to severe turbulence exists because of the following factors:

- Reduced cruise gust environment
- Improved National Airspace Systems
- Improved weather forecasting
- Refined stability augmentation system (SAS)
- Greater structural margins
- Improved ride qualities in turbulence

An expanded view of these and other factors associated with turbulence operations is provided in the following paragraphs.

3.2.2 Atmospheric Structure

Extensive velocity, normal acceleration and altitude (VHG) sampling programs in the lower atmosphere (i.e. below 35,000 ft) have identified turbulence levels associated with normal avoidance practice. Limited sampling of the upper atmosphere (i.e. 25,000 to 75,000 ft) by U-2 aircraft have supplemented the lower altitude data. These data identify an envelope of turbulence intensity (Fig. 3-1) which has a remote probability of occurrence in normal operations.

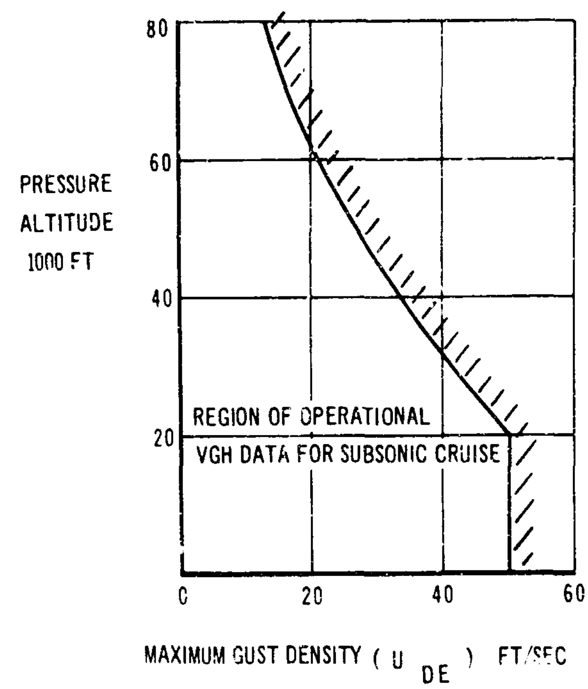


Figure 3-1. VGH Sampling Envelope From Airplane Operations (Including U-2)

These same sampling operations have produced well defined information on the average amount of time spent in turbulence and the probability of encountering various levels of turbulence (Figs. 3-2 and 3-3).

3.2.3 Avoidance

Greater turbulence avoidance will be possible under the planned ATC system. Enroute (ARTCC) and terminal departure/approach (DEP/APP) radar systems are planned which will incorporate auxiliary radar monitoring systems adjusted for weather detection only (Fig. 3-4). An expanded controller team having one additional man per team will space-phase both traffic and potentially turbulent weather zones. Although weather radar detects precipitation areas only, experience with the system will

greatly improve turbulence avoidance capabilities.

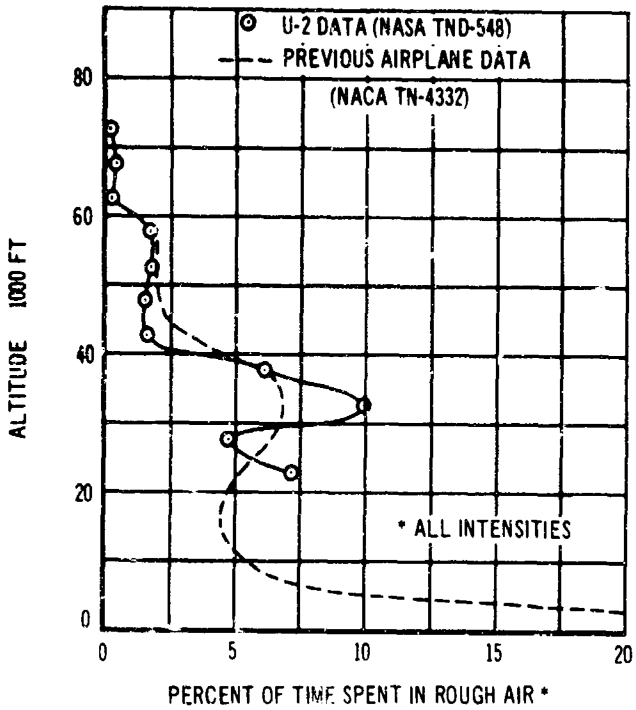


Figure 3-2. VGH Exposure Record

It is expected that meteorological forecast capabilities will be improved by the SST era. Such improvements will include better definition of tropospheric properties as related to turbulence (e.g. thunderstorms and jet streams).

Although there is presently an insufficient amount of information on the incidence and mechanisms of turbulence in the stratosphere, it is reasonable to expect significant advances in turbulence prediction techniques. Current research (USAF, NASA, ESSA) should lead to forecast techniques which will allow avoidance of disturbed stratospheric areas. The relative utility of a system for automatic detection, recording, and reporting may be better judged after more results are in from such current research efforts as the USAF HICAT program.

Considerable effort is being expended to develop a clear-air turbulence detection system with adequate warning for the pilot. Pilot avoidance action depends on warning time and on how well the system defines the turbulent cell. A promising detection technique is meter-wave radar;

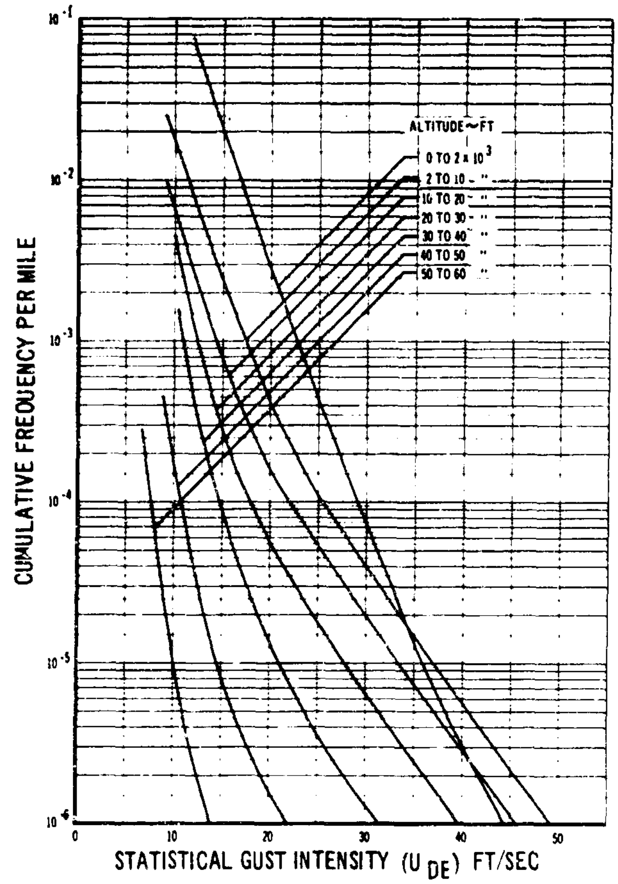


Figure 3-3. VGH Turbulence Intensity Record (Averaged)

unlike weather radar it does not depend on backscatter from particulate matter but depends instead on backscatter from refractive eddies in the atmosphere. Experiments by Boeing with both ground and airborne meter-wave radar have been moderately successful. Although a special CAT detection system is not presently planned for the B-2707, company participation in CAT detection research and of detection system development will continue.

3.2.4 Handling Qualities

The airplane is designed to provide optimum performance in turbulent conditions. Positive damping about all axes is provided by the stability augmentation system (SAS). In addition, considerable SAS authority is provided for handling qualities improvement. This authority is adequate for the most severe turbulence, and saturation of the SAS is not a limiting factor. The SAS also

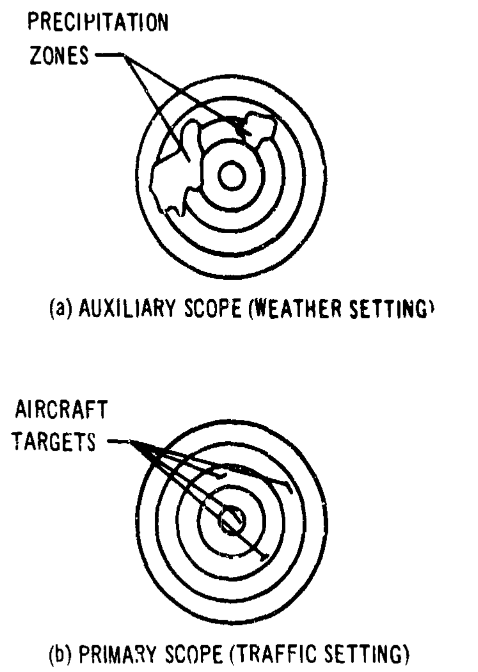


Figure 3-4. Planned ATC Radar Display (1975)

provides an attitude-holding capability which permits low-gain attitude stabilization in severe turbulence with the autopilot disconnected. Reliability is provided by triplication and monitoring so that the SAS is fail-operational with no degradation in system performance. Pitch and yaw remain fully operational after two channel failures while roll remains operational after one failure and passive after two failures. Detailed discussion of SAS design is presented in the Aerodynamic Design Report, V2-B2707-3.

3.2.5 Structural Margins
Gust margins in turbulence will be greater than in the past due to the modifying influence of consistently greater wing sweep on design criteria relationships. In addition, a wing-aft position for descent may be retained if turbulence is expected in the terminal area. A considerable amount of load relief in turbulence is afforded by the reduced lifting properties inherent in wings-aft operation. Additional relief is afforded by any wing flexing which does occur. Figure 3-5 shows typical gust margins with the wing at 42 degrees sweep and at 72 degrees sweep. High-

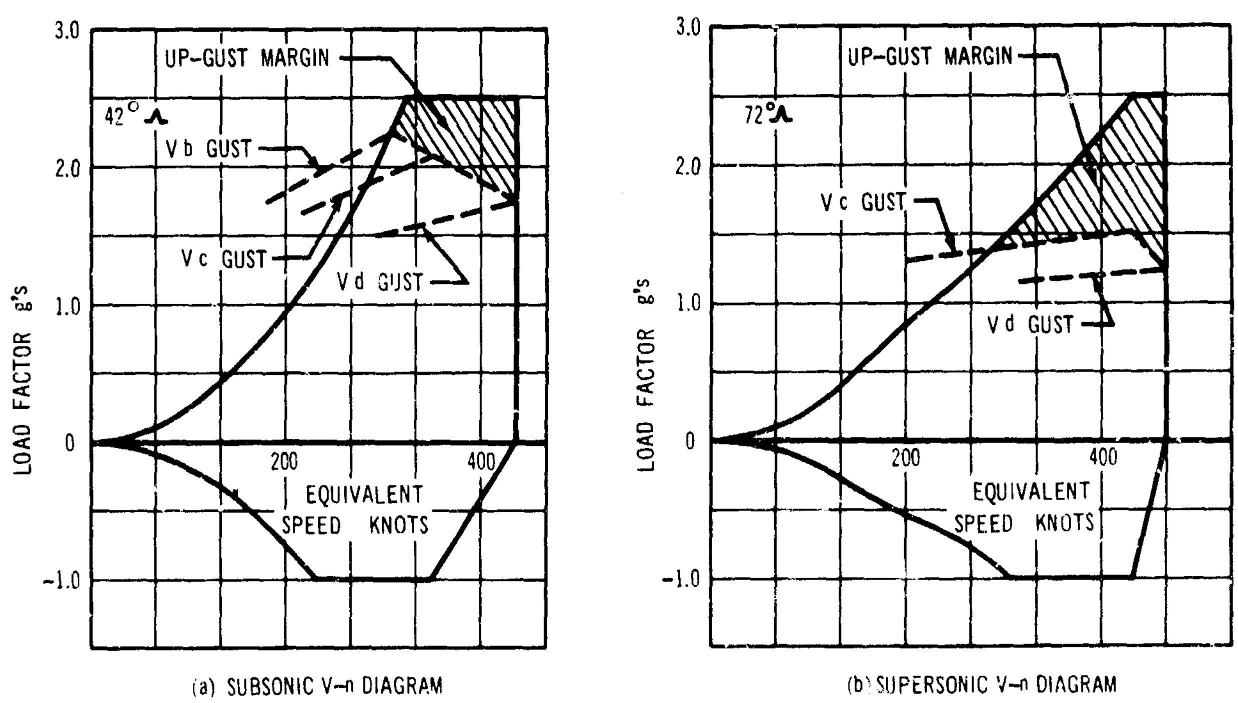


Figure 3-5. Representative Gust Margins

altitude gust sampling programs to date have indicated a very significant reduction in gust environment for cruise (See Fig. 3-1). The overall subject of design for gust loads is discussed extensively in Airframe Design Report, Part C, V2-B2707-7.

3.2.6 Ride Comfort

Improved crew and passenger environments in turbulent air are anticipated for any wing-sweep position, particularly during wing-aft operation because of reduction in the lift curve slope. The longer, more flexible, fuselage structure is expected to improve conditions because human response at lower frequencies (near 1 cps) results in less discomfort than at the higher frequencies (4 to 6 cps) characteristic of existing civil transports. Wing-forward operation should be superior to that of present subsonic jets principally because of the lowered fuselage frequency. The greater wing sweep (42 degrees) employed for subsonic flight provides an additional improvement in ride comfort. An expanded discussion of ride comfort is presented in Airframe Design. Part C, V2-B2707-7, with particular emphasis on B-70 ride qualities. Coordination with the FAA, the NASA, and North American Aviation Inc. is being maintained and B-70 data evaluation will continue. Phase III activities are planned to include additional moving-base simulator studies beyond that discussed in V2-B2707-7. These studies will include investigation of possible effects of low damping in elastic modes and of possible methods of improving the damping in the event significant effects should be shown to exist. Preliminary information in this regard is expected at an early date as the result of company B-52 flight test programs presently being performed at Wichita under Air Force Contracts AF 34(615)-3753, Load Alleviation and Mode Stabilization Program, and AF34(601)-25146, Stability Augmentation System for Improved B-52 Structural Life.

3.2.7 Gust Penetration

Subsonic turbulence penetration speeds for anticipated zones of moderate to severe turbulence are 320 kn wings fully aft and 300 kn wings forward (42 degrees sweep). Supersonic penetration speeds may have any value between 320 kn and V_{MO} minus 50 kn as desired to adhere to the optimum flight profile for performance or economy. The airplane has excellent handling qualities in turbulence in either configuration, or in any intermediate configuration, as discussed under Par. 3.2.4. Subsonic turbulence penetration speeds for intermediate wing positions are maintained at 300 kn as shown in Fig. 3-6.

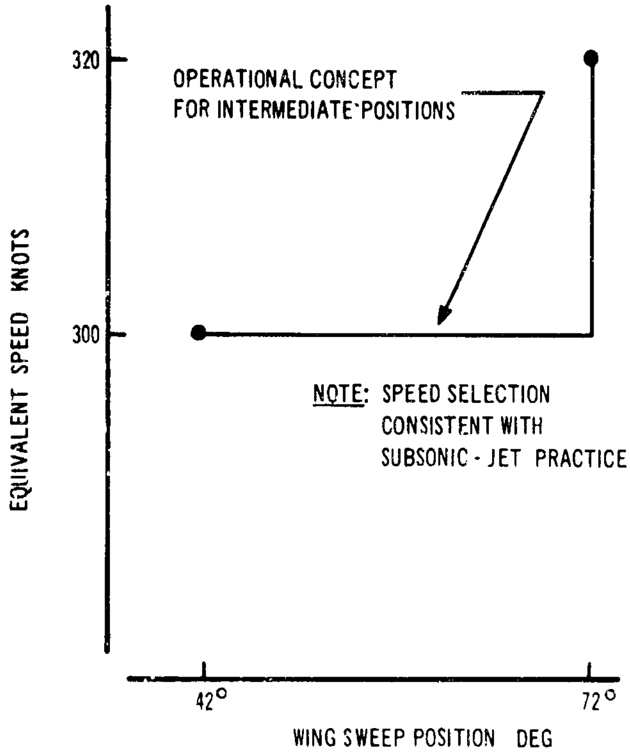


Figure 3-6. Subsonic Penetration Speeds for Moderate to Severe Turbulence

3.2.8 Operational Techniques

Special operating techniques for use during severe turbulence conditions have been developed in recent years and have become an operational must.

Pilot operation is as follows:

a. Maintain low-gain attitude stabilization, i.e. fly loose.

b. Allow moderate variation in speed and altitude.

c. Do not change trim to any significant extent.

Autopilot engagement is as follows:

a. Disconnect promptly (SAS provides low-gain attitude stabilization)

b. Do not leave on MACH HOLD, ALTITUDE HOLD, OR RATE OF CLIMB HOLD modes.

3.3 OZONE
The ozone concentration in the atmosphere, especially in the stratosphere, is of sufficient magnitude to influence the B-2707 design (Fig. 3-7). The stratospheric ozone concentration, which reaches 8 ppm by volume at 70,000 ft, must be reduced by a factor of approximately 50 before entering the passenger and crew compartments (Refs. 7 and 8).

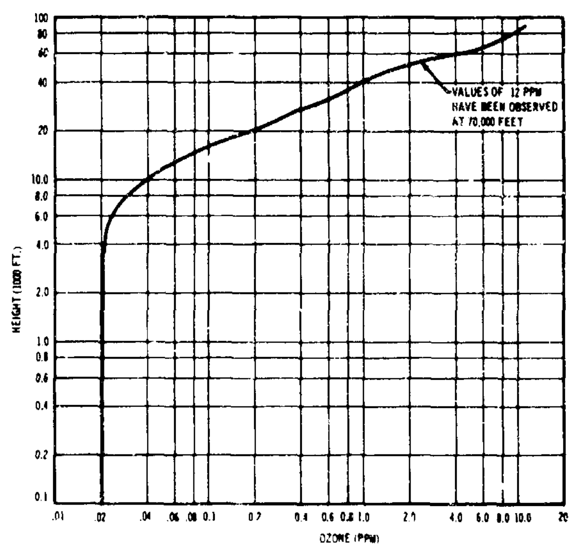


Figure 3-7. Ozone Concentration in Spring at High Latitude in Northern Hemisphere

3.3.1 Passenger/Crew Protection
The maximum ozone concentration allowables for the crew and passenger cabins, as established in the Tentative Airworthiness Standards for Supersonic Transports, are 0.2 ppm during normal operations. This allowable may be exceeded for short periods and is very close to ozone concentrations now being experienced in current jet aircraft (Ref. 9 and Fig. 3-8).

An ozone monitoring system is provided in the airplane to give the crew a continual indication of the cabin ozone concentration. Analysis, based on published test data, shows that the ozone con-

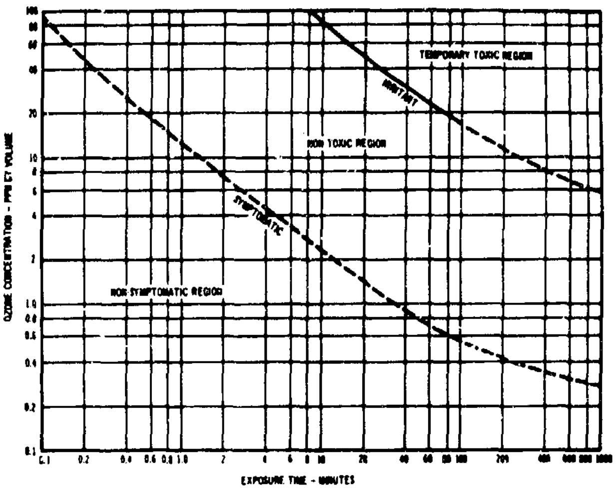


Figure 3-8. Prolonged Ozone Inhalation and its Effects on Visual Hemisphere

centrations in the cabin can be held to a concentration of 0.1 ppm or less during all phases of the flight. The disassociation of ozone is accomplished in the air-conditioning subsystem by high temperatures (500°to 1,000°F) together with the catalytic action of nickel-plated heat exchanger fins. For details of the ozone disassociation analysis, see the environmental control system description in Airframe Design Report, Part A, V2-B2707-6-1.

3.3.2 Materials Protection
In addition to the possible toxic effects of ozone, the degradation effects on nonmetallic materials, especially rubbers, is also a consideration. Ozone decomposes at elevated temperatures. The exterior surface temperature of a supersonic transport at cruise altitude will be close to 400°F. The thermal barrier of the shock waves is expected to decompose the ozone. However, the effectiveness of this decomposition has not been fully determined. Consequently, materials are being chosen for their ozone resistance in addition to their high temperature stability. The high surface temperature constitute the major detrimental environmental condition for most materials. Specific material choices are documented in Airframe Design Report, Part D, V2-B2707-8.

3.4 RADIATION
The galactic cosmic radiation, both primary and secondary components, are of such low level that they will create no hazard to the flight crew and passengers. Solar flares will occasionally generate dose rates in excess of present AEC human

tolerance levels. Investigations are continuing to determine the dose rate considered high enough to warrant descent to a lower altitude at the onset of a solar particle event. Data obtained from the SST Radiation Environment Study, being conducted by the Air Force Weapons Laboratory, will be used to aid in this study.

Solar ultraviolet is calculated to produce only minor degradation upon the airplane external nonmetallic surfaces when combined with high temperature and low pressure.

3.4.1 Passenger/Crew Protection
Provisions for the installation of an onboard radiation monitoring system for the detection of the onset of solar particle events are included in the basic design. In the operational phase, the B-2707 will be linked to the NASA Solar Flare Prediction Network and to solar observatories via ground-based computers. The flight crew will be advised to descend to lower altitudes in sufficient time to prevent over-tolerance exposure due to a high-intensity solar flare event.

3.4.2 Materials Protection
Simulated ultraviolet radiation as found at 70,000 ft is being combined with simulated flight temperatures and pressures in environmental tests to evaluate exterior materials. Selection and qualification of nonmetallic exterior materials is being based on these environmental tests (Airframe Design Report, Part D, V2-B2707-8).

Discoloration of some paints exposed to solar ultraviolet radiation usually occurs at a decreasing rate until a saturation discoloration is reached. This saturation level is reached in 500-1,000 hours of exposure to solar radiation (Ref. 10). Paint, specified for external markings, has been selected to withstand normal radiation effects.

For corpuscular radiation, a dose of the order of 10^{15} particles per square centimeter is necessary to affect paint films (Ref. 11). If the airplane were in radiation zones one third of the time, a flux of the order of 10^8 particles per square centimeter per second would be necessary to give a dose of 10^{15} particles per square centimeter in one year of operation. Fluxes of this magnitude are found only in the heart of the trapped electron and proton belts and in the solar flares and winds beyond the earth's electromagnetic field.

The corpuscular radiation at the cruise altitudes should not cause or contribute to any significant degradation of the materials of the airplane.

3.5 PARTICULATE MATTER
Particulate matter is not expected to cause any effects to the surfaces of the B-2707 either by erosion or chemical action because the concentration in the stratosphere is so small. These aerosol particles, however, do collect radioactive materials injected into the stratosphere by nuclear event. This should cause no problem in the future unless the amount of radioactive material released in the atmosphere increases.

The total aerosol mass concentration in the stratosphere is approximately 1.5×10^{-16} gm/cm^3 at stratospheric temperature and pressure (Ref. 12). An aircraft traveling at 1,800 mph would encounter 4×10^{-6} gm/cm^2 of aerosol particles per hour on a frontal area if there were no deviation of the airstream. However, the effect of the large size and the configuration of the B-2707 on the airflow would preclude effective impaction of aerosol particles. Further, the concentration is so low that no surface effects from aerosol particles is expected either from erosion or chemical action.

The natural aerosol particles in the stratosphere can collect radioactive materials injected into the stratosphere (Ref. 12).

The following statement on radioactive particles in the stratosphere was published by Teweles and McInturff on May 1966 (Ref. 8):

> "Radioactive material naturally present in the stratosphere is not significant as a hazard to SST operations. Furthermore, artificially injected radioactive material is negligible at the present time and will remain so as long as there is a moratorium on the testing of nuclear devices in the atmosphere."

The B-2707 has provisions for incorporating radiation detection and filtering equipment in the event of an increase in radioactive particle concentration in the stratosphere (Par. 3.4.1).

In addition to the aerosol particles, precipitable water particles must be considered. In the stratosphere these particles will be ice in the form of hailstones, snowflakes, or ice crystals.

These particles may on occasion be encountered at supersonic cruise altitudes. Supersonic flight through a thick cloud of ice particles should be avoided, since reports show that considerable aircraft damage has been sustained in thunderstorm areas. However, supersonic flights through thin cirrus clouds have caused no detectable damage to aircraft (Ref. 8). Weather radar, as described in Par. 2.8.2, is included in the B-2707 and is capable of detecting thunderstorms which are usually associated with significant formations of ice crystals (Airframe Design Report, Part A, V2-B2707-6-1).

The impaction efficiencies for a supersonic transport will be low for most surfaces. For rain erosion protection a ceramic cap is to be used on the tip of the radome.

3.6 NATIONAL AIRSPACE SYSTEM COMPATIBILITY

The National Airspace System (NAS) provides the capability to monitor airplane relationships, to adjust flight paths to prevent collision situations, and to provide expeditious movement of airplanes. The NAS must continue to be responsive to our national aviation goals and objectives, and be capable of timely and orderly implementation within the limitations and constraints of the practical world. The NAS is comprised of heterogeneous elements, which are: airplane, pilot, airport, aeronautical information, ground controller communications, navigation, rules and procedures, and ATC; the ATC being the supervisory element. All of these components must be integrated in any airspace utilization system. The system that provides for the movement of airplanes must be cognizant of the above diverse elements because of their intimate interaction. No element can be omitted without a degree of loss in system integrity in any feasible and effective airspace utilization system.

The compatibility of the airborne communications navigation electronics with the NAS is described in the following paragraphs.

3.6.1 Air Traffic Control

The vital role of the air traffic control (ATC) requires a projection of its growth to evaluate and ensure compatibility of interfacing systems. In designing a compatible ATC system, the following items must be considered:

- Definition of the problem, comprising air traffic density distribution, flow pattern, altitudes and speeds
- Environment, modifications, rearrangement, or evolution of ground station equipment to provide the necessary growth potential and accuracy requirements under all environmental conditions
- Design choices, definition and description of design principles and associated equipment techniques
- ATC automation, description of ATC function and related data processing and display equipment
- Operational summary, description of flight through the compatible ATC system
- Timing, scheduling for the progressive development and implementation of new equipment

The B-2707 airborne electronic equipment is consistent with the present NAS environment and exhibits the growth potential necessary to be compatible with the planned ATC ground facilities at the time of SST inception into the airline fleets. In addition, the B-2707 has flight characteristics in the terminal area compatible with other contemporary airplanes.

3.6.2 Communications

3.6.2.1 VHF Communications

Presently, the ATC system is faced with the problem of expansion of the system's communication capabilities. Air traffic controllers are often required to share the use of channels between control functions. A direct consequence is the need for additional very high frequency (VHF) communications channels.

In general terms, the solution to the problem requires more effective use of the radio spectrum. Channel splitting offers some measure of relief, but does not fully resolve the problem. A more efficient use of the radio spectrum embodies the data-link communications technique, which significantly reduces the communications time required for a particular airplane's message transmission. With the advent of a time-sharing data link, air traffic controllers will be able to share the use of frequencies for various control

functions. Consequently, the problem of assignment of frequencies to ATC ground units will be a less critical problem. The appropriate ground unit will be automatically alerted by a particular airplane's code, regardless of the number of airplanes transmitting on that specific frequency.

The application of data link, with the accompanying increased navigation aid accuracy in the ATC system, will permit further reduction of cruise communications and will permit the airplane's position in time and space to be accurately known at all times. Correspondingly, the terminal area communications traffic will be significantly reduced.

With the implementation of the time-sharing data link communications, the VHF spectrum will be provided with the number of channels necessary for the ATC communications.

The VHF transceiver selected for the B-2707 has such features as: provisions for future use of angle modulation, synthesizer frequency control, adequate end-to-end checking of signal integrity, 25 kHz channel spacing for anticipated increased communications load, satellite communications, and data link. With these features, the proposed VHF communication system will be compatible with the present and the future ATC system.

3.6.2.2 HF Communications
High frequency (HF) communications (2-22 MHz), as employed by the commercial airlines, provides long-range, over-the-horizon voice communications. This system is not required over the continental United States because of the availability of the more reliable VHF communications network, but will be available for use as a backup.

Presently, HF communications are required for the continental United States to Alaska/Hawaii flight routes. The requirements for HF communications for the Alaska flight routes may be eliminated by the implementation of extended-range VHF communications. However, the HF requirement for the Hawaii flight routes will continue until either the VHF satellite communications system or the VHF buoy system becomes operational.

The HF communications transceiver proposed for the B-2707 will provide the necessary frequency coverage to operate with the present and planned HF communications ground facilities. The modes of operation available in the HF will be upper sideband, amplitude modulation, and data. The data mode will be compatible with future data-link operations.

3.6.2.3 Satellite Communications (Satcom)
Current and forecasted air traffic densities in the North Atlantic routes necessitated the proposed implementation of a more reliable communications system than the present HF service. As currently envisioned, this new communications system will be provided by VHF relay through a synchronous satellite. Due to the coverage of the proposed worldwide (excepting the polar regions) satellite network, this system will be available to airplanes operating in national airspace.

However, in the continental United States, a satellite communications system will do little to enhance the VHF communications network other than to add another mode of direct communication between airplanes and company stations. The flight routes terminating in the continental United States where Satcom could provide primary communications are the United States to Hawaii/Alaska routes and arriving international flights. Satcom may evolve into an ATC system aid to provide ranging and other information necessary to locate an airplane in a three-dimensional environment; however, initial satellite usage will be confined only to the communication function. This communications network will provide four to six channels in the upper range of the spectrum of the VHF Aeronautical Mobile Communication Service.

The proposed VHF communication system for the B-2707 includes provisions for the implementation of the equipment complement required for an airborne Satcom system, and therefore, establishes compatibility for any Satcom usage envisioned in the future National Airspace System.

3.6.2.4 Ocean-Based Communications
The buoy system, as recently proposed and defined by the British Air Ministry for use along the North Atlantic flight routes, consists of a series of hardwire connected, large, stable installations. These strategically located buoy installations will house permanent maintenance crews, and will have antennas extending well above rough sea levels.

This buoy system concept, or a similar arrangement, could be directly applicable to the continental United States to Hawaii/Alaska routes, and also provide a method of fulfilling the requirements of the National Airspace System.

The B-2707 communications system is compatible with the proposed buoy system. These buoys will be utilized as relays to process the VHF and ATC beacon (secondary radar) signals from the airplane to continental ATC centers via the hardwire circuits.

3.6.2.5 ATC Transponder
Two major problems facing the ATC system are the reduction of voice communications and expansion of the capability of the ATC Radar Beacon System (ATCRBS) to accurately display the position of airplanes within the control area.

The B-2707 ATC transponder contributes to the solution of these two problems. The transponder can decrease the number of communications by transmitting, to a ground facility, a code which represents certain flight conditions. Codes indicating emergency conditions or complete communications failure are included in the ATC coding system.

The implementation of the automatic altitude reporting function also will aid in relieving the communications workload and in pinpointing the airplane's position. This function will provide the air traffic controller with each airplane's altitude, without the need for voice communications.

Provisions for a discrete airframe identification function are included in the transponder. The transponder is compatible with the National Airspace System because it has the capability of operating with 4096 reply codes, two- and three-pulse side-lobe suppression, and will operate with the functions discussed above.

3.6.3 Navigation

3.6.3.1 Inertial
Inertial systems will enhance airspace utilization because they are self-contained navigators capable of precision worldwide operation under any weather conditions and independent of ground based or other external aids. They are dynamic devices capable of providing accurate guidance and attitude information during the long-duration, high-accelerations profiles, and high-speed and altitude-cruise conditions. The accuracy of the airborne inertial navigation system (INS) for the B-2707 is expressed in circular error probability (CEP), without updating, of 1.5 nmi/hour for subsonic flight and 3.3 nmi/hour for supersonic flight. Their ease of operation, automatic capability, and continuous system integrity monitoring will result in reduced flight crew workloads.

Use of inertial navigators will enhance direct dispatch clearing and parallel routing between terminals allowing more efficient airspace utilization and operating economy. They will provide continuous position information necessary for accurate position reporting and will be compatible with future data-link operations. Wind information is continually computed for weather reporting. Precise position data can be used to minimize the effect of sonic boom.

With the future National Airspace concept of parallel routing being planned by the FAA, the INS for the B-2707 will be the primary navigation device used in the accomplishment of this more efficient method of utilizing airspace.

3.6.3.2 Automatic Direction Finder and LORAN
The automatic direction finder (ADF) system on the B-2707 will be used primarily as a backup system for terminal area and long-range navigation. Over the continental limits of national airspace, the ADF becomes the subordinate system for the INS and the VHF omni-range (VOR) for enroute navigation. The ADF can provide enroute position fixes in areas where VOR is not usable or available, but still remains a backup system to the INS. In terminal areas, the ADF can be used by the flight crew as an additional aid for position fixing.

The ADF is compatible with the present ground stations, and examination of the future concept of the National Airspace System indicates continued congruity. After the INS becomes generally accepted for airline operations, the redundancy of the ADF systems can be lowered.

LORAN can also be used for long-range navigation. Provisions are included in the B-2707 to accommodate this system.

3.6.3.3 Pictorial Display
Review of the various available and projected implementations of moving map displays has failed to justify assignment of prime panel space

to a moving map display. Review and analysis of requirements and capabilities of pictorial map displays will continue to determine if benefits can be derived from devices or concepts developed in the future.

3.6.3.4 VORTAC

The proposed very high frequency omni-range (VOR) and distance measuring equipment (DME) will be functionally compatible with the VOR and DME ground equipment. The VOR receiver has the ability to utilize the signal from doppler VOR stations, which the FAA has installed. The DME interrogator can presently operate on 126 channels with the built-in capability for utilizing 252 channels when channel splitting is implemented. Also, the DME and VOR systems will be operable to a 288 nmi range at altitudes above 60,000 ft mean sea level.

When flying below 45,000 ft, the DME and VOR system installed on the B-2707 will be operationally compatible with ground installations to the same extent as the equipment installed on present-day aircraft. However, when operating above 45,000 ft, there is a possibility that the airplane will be within line-of-sight range of two ground stations transmitting on the same channel. This would cause the receiver to lose the original signal in the transition region where neither signal is 8 db stronger than the other. After passing through this region, the second signal could predominate and a different bearing and/or distance would be indicated. Unless the pilot was continuously cognizant of the VORTAC indicators, the change of ground stations reception could cause confusion.

The solution to this problem is the planned implementation by the FAA of specific VORTAC ground stations which will allow VORTAC operation at high altitudes (above 45,000 ft) on a noninterference basis.

3.6.3.5 Instrument Landing System

The B-2707 instrument landing system (ILS) is superior in accuracy and reliability to those systems successfully used in the Boeing Low-Weather Minimums Test Program, while remaining compatible with present-day ILS ground installations; hence, no ground equipment modifications are required over those presently planned for Category III operations. The B-2707 localizer, glide-slope receiver, and radio altimeter systems are compatible with the environmental design and accuracy requirements for Category II and III landing systems. They are further discussed in Par. 2.8.2.

The independent all-weather testing programs on 707-727 airplanes conducted at Boeing facilities, coupled with detailed failure mode and effect analyses and accuracy studies on existing ILS systems, have substantiated the compatibility of the selected equipment with the approach and landing requirements of the National Airspace System.

3.6.3.6 Radar

The cloud tower tops of cumulo-nimbus formations will occasionally penetrate the cruise altitudes in the flight corridors assigned to the B-2707.

In order to avoid such weather conditions at supersonic speeds and remain compatible with the National Airspace System concept, a weather radar system is installed with detection ranges sufficient to allow the pilot to accomplish an avoidance maneuver characterized by the least lateral deviation from the prescribed course. These selectable ranges of the airborne weather radar are 0 to 30, 80, 150, and 250 nmi with an expanded display range capability of 100 to 250 nmi. Aside from resultant maintenance of an efficient and economical flight path due to the least lateral deviation maneuver, the extended detection range of the weather radar yields additional time for the pilot to evaluate and choose the best possible avoidance maneuver. In addition, the least lateral deviation maneuver ensures that hard-over maneuvers, resulting in exceeding the prescribed cruise corridor limits will be avoided.

Improvements in airplane weather radar sensitivity and antenna stabilization performance will increase the quality of the weather information displayed to the flight crew.

Improved flight operation under adverse weather conditions within the terminal area ATC structure will be possible. Greater avoidance capability of weather hazards will be possible under the 1975 ATC system due to improvements in the ground stations and airplane weather radar system. An expanded controller team having an additional man per team will space-phase the air traffic with the aid of the standby radar monitoring system optimized for performing the weather functions.

3.7 AIRCRAFT AND ENGINE GROUND HANDLING AND SUPPORT

3.7.1 Summary

Successful ground handling and support techniques developed for the current generation of Boeing jet airplanes can be easily updated to accommodate the B-2707. The B-2707 has been designed with special considerations for state-of-the-art methods and existing and planned ground equipment to minimize the impact on airline ground operations and equipment investment. It is conservatively estimated that the B-2707 will be compatible with 60 to 70 percent of the ground handling and servicing equipment supporting subsonic aircraft in the 1970's.

Considerable preliminary design and analysis effort have gone into the handling and service features of the airplane, so that as many service actions as possible can be performed simultaneously without interference with other services, and without jeopardizing safety. The B-2707 ground handling characteristics will permit enroute flight service within the desired capability of 20 minutes. The desired capability of 30 minutes for turnaround service is met for all operations.

Boeing jet transports are designed with the objective that any individual maintenance task can be accomplished in 8 hours downtime. This same objective, applied to the B-2707, allows a flexible maintenance program, adaptable to the many divergent operational requirements of domestic and international airlines.

The scheduled line maintenance program for the B-2707 consists of three levels of checks: daily check, intermediate check, and periodic check, performed repetitively at progressively higher airplane flight hours. The ground elapsed time goals for the daily, intermediate, and periodic checks are 1, 4, and 16 hours respectively. The major work zones on the B-2707 are well dispersed and access is good. Scheduled line and overhaul maintenance work requirements on the B-2707 will be similar to current and advanced subsonic jets.

To facilitate scheduled and unscheduled maintenance, the airplane incorporates features, such as built-in self test, aircraft integrated data system (optional), and quick disconnect equipment, to allow rapid troubleshooting of systems, rapid replacement of components, and conventional repair of minor structural damage. A "bootstrap" method can be used to raise and lower the entire propulsion pod (engine, inlet and exhaust) or the engine section, inlet and thrust reverser nozzle individually. A minimum of ground support equipment will be required to support the onboard maintenance capabilities of the airplane. A maintenance analysis was conducted during the B-2707 configuration development period to define the line and base maintenance support requirements. See Maintainability Program, V4-B2707-15.

The results of detailed laboratory tests and heat transfer analysis indicate that residual heat in the airplane structure due to aerodynamic heating will not affect normal ground servicing operations (see Par. 3.7.2.3). Unscheduled maintenance in heavy structural areas may require auxiliary cooling to permit rapid access, inspection, and replacement with ground times necessary to achieve an economical maintenance operation.

The complete listing of ground support requirements defined to date is included in GSE Requirements Specification, D6A10180-1.

3.7.2 Ground Handling and Servicing

The company has applied the jet transport ground handling and servicing methods developed for the current series of subsonic airplanes to the B-2707 supersonic transport. Adoption of the best of these methods and utilization of the extensive airline experience with Boeing airplanes will permit the B-2707 to be easily integrated into the airline ground operation environment.

A general servicing arrangement for the B-2707 is shown in Fig. 3-9. Ground handling and servicing of the B-2707 can be accomplished, using the same type of equipment and facilities normally available at major jet transport terminals.

Modifications of existing ground support equipment will be necessary in some cases, to enable service personnel to reach certain B-2707 service panels. Most of these modifications will also be necessary to support the large subsonic jets currently programmed for airline use.

The high degree of compatibility of the B-2707 design with airlines ground support equipment is illustrated by the matrix shown in Fig. 3-10. By

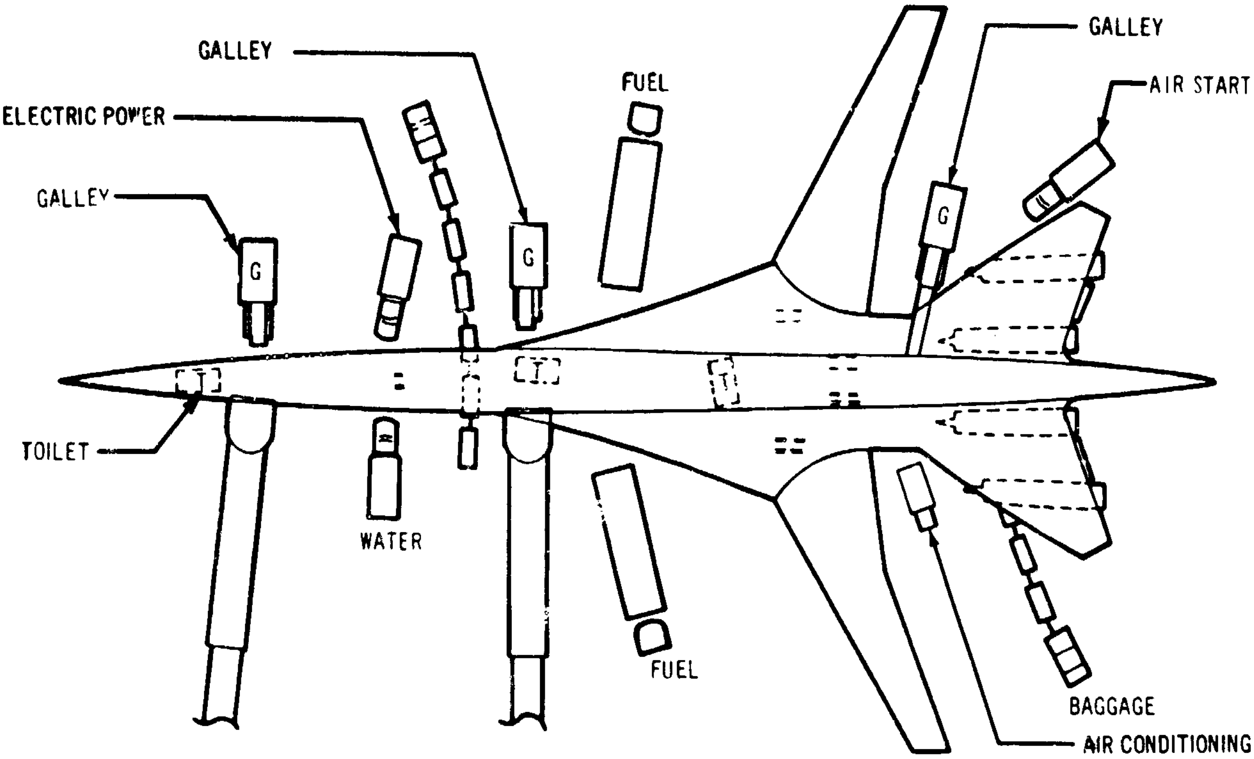


Figure 3-9. General Service Arrangement

designing the B-2707 for efficient ground handling and service, using state-of-the-art methods and ground equipment, the impact of the supersonic transport on airlines' ground operations and equipment investment will be minimized. It is recognized that the B-2707 will not enter airline service for several years, and that to ensure effective and efficient airline ground operations in the interim, continuous replacement and improvement of ground equipment will occur. The company will conduct a continuous ground support analysis and evaluation program so that recommendations for ground handling and servicing techniques, and equipment will always be within the capabilities of the airlines and industry.

Ground handling and servicing at originating, enroute, and turnaround stations include all actions, other than maintenance, which must be performed by ground personnel to prepare the airplane (1) in the case of origin or turnaround servicing for a flight involving maximum range and payload or (2) in the case of enroute servicing, for the remaining portion of the flight or to the next enroute station. Under full-load conditions, 100 percent of the payload must be loaded

GSE STATUS

FUNCTIONAL REQUIREMENTS	EXISTING INVENTORY	MODIFIED INVENTORY	EXISTING STANDARD	NEW DESIGN
TOWING		✓		✓✓
PASSENGER SERVICE	✓			
BAGGAGE CARGO		✓		
FUELING	✓			
GALLEY SERVICE		✓ (FWD)		✓ (AFT)
WATER SERVICE	✓			
TOILET SERVICE	✓			
AIR CONDITIONING				
ELECTRICAL POWER	✓			
INTERPHONE COMMUNICATIONS	✓			
CLEANING	✓			
ENGINE STARTING	✓			✓✓

PRIME ✓
ALTERNATE ✓✓

Figure 3-10. Airline – Air-Terminal – GSE Requirements

and unloaded at the origin and turnaround stations, while at the enroute station, 50 percent of the payload must be exchanged. In addition to payload exchange, the servicing procedures (Par. 3.7.3.3) must be safely and efficiently completed in the station environment within 90 minutes for the origin/turnaround stations under normal use conditions, with a desired servicing capability of 30 minutes, and within 30 minutes for the enroute stations under normal-use conditions, with a desired servicing capability of 20 minutes.

Analysis of the requirements for ground operations indicates that the ground handling and service time objectives, as stated above, can be achieved. The B-2707 ground handling characteristics permit enroute service within the desired capability of 20 minutes for all operations except those requiring maximum fuel load. A complete fuel load for an enroute stop can be supplied in less than 30 minutes. The desired capability of 30 minutes for turnaround service is met. The following paragraphs discuss, in detail, the time-phased ground operations. Composite timelines for these operations are shown in Figs. 3-11 and 3-12.

3.7.2.1 Ground Handling, Operations
Ground handling is that portion of ground operations during which the aircraft is being towed or jacked by ground personnel.

a. Towing. Trade studies have been conducted to determine the best method for maneuvering and positioning the B-2707 at the air terminal. At this time these studies indicate that the present method of moving jet aircraft with a towbar and tow tractor, still provides the most economical and efficient means of airplane movement. Studies of such methods as cable winching, airborne wheel mover units, and externally-powered individual wheel motors, will be conducted to ensure optimum operational methods of towing.

A static drawbar pull of approximately 50,000 lb is required to move the 675,000 lb gross weight B-2707 straight ahead on dry concrete up a 3 percent grade. This will require a tow vehicle weight of 60,000 to 70,000 lb, depending on the traction developed. Under adverse conditions, such as snow or ice, a tow vehicle of over 100,000 lb gross weight may be required.

Figure 3-13 illustrates the ground motive force requirements.

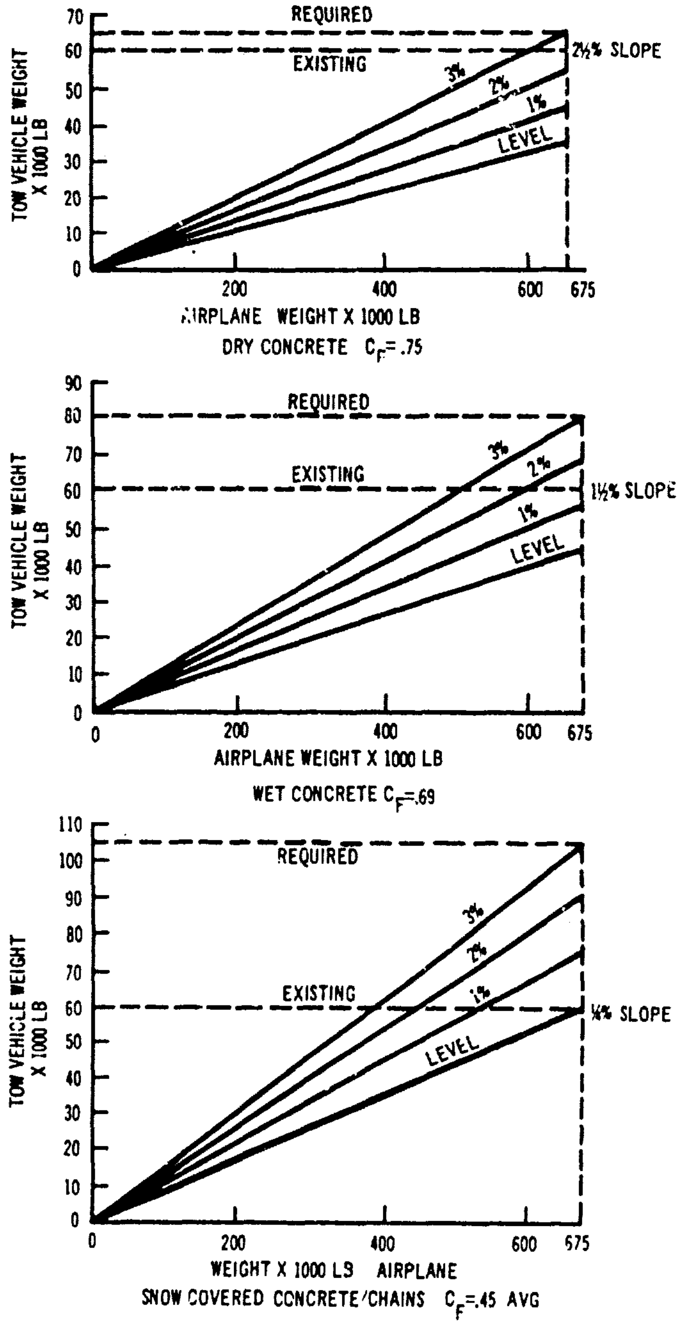


Figure 3-13. B-2707 Ground Moving

Towing adapters are installed on the B-2707 nose and main landing gear to provide forward and aft towing capability. Provisions for nose gear axle-end towing will be provided, if desired by the operator.

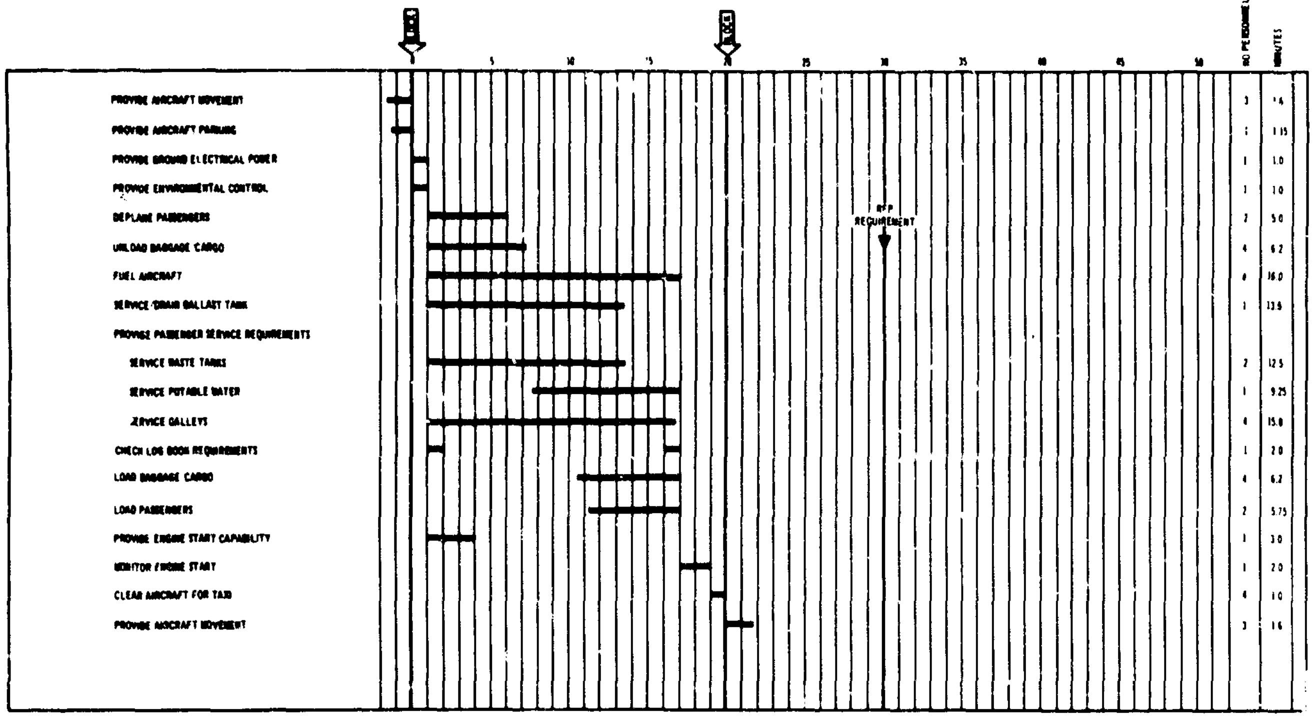


Figure 3-11. Enroute Service

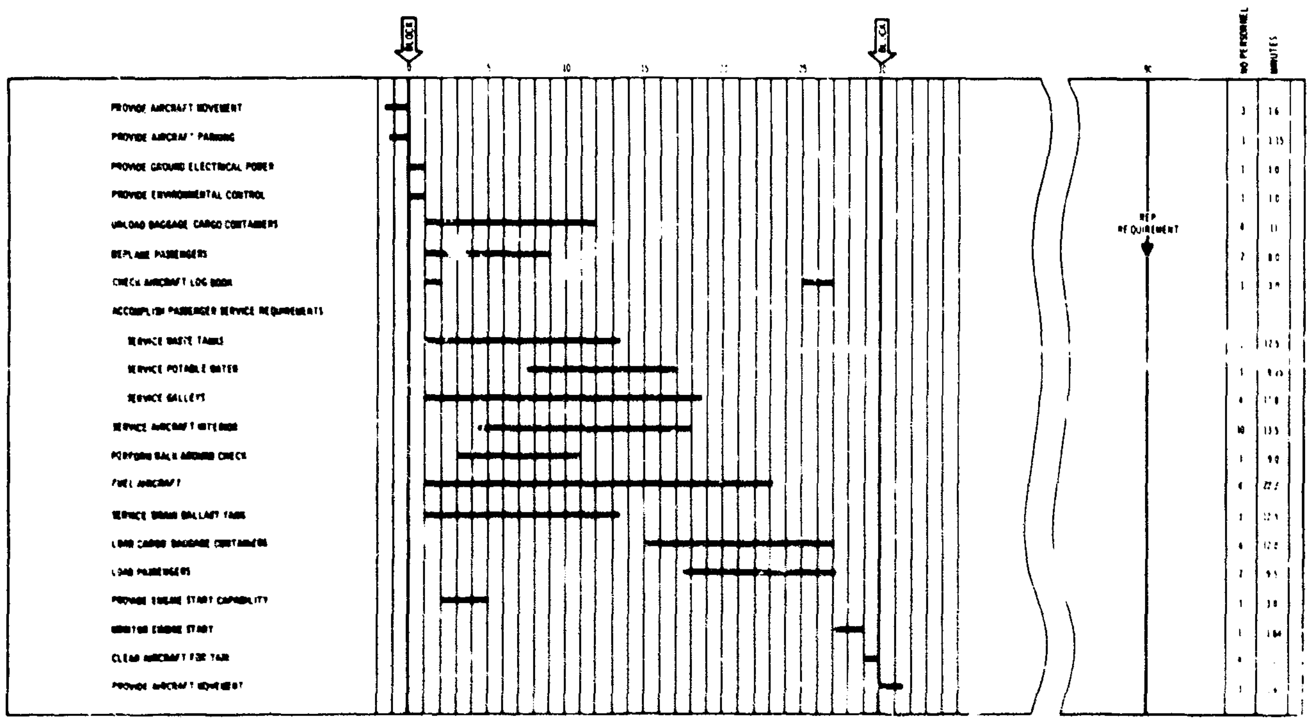


Figure 3-12. Origin/Turnaround Service

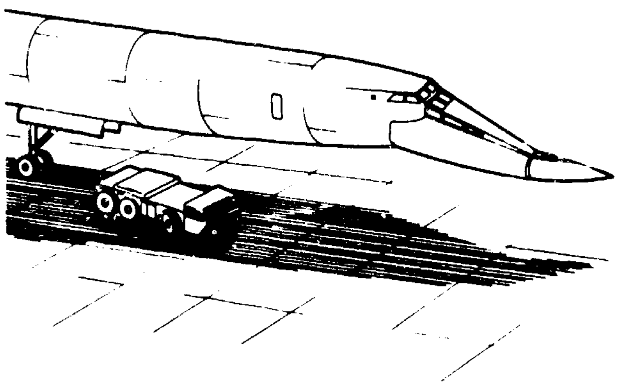


Figure 3-14. Towing

A low-profile tow tractor, (Fig. 3-14) offers the most feasible approach to ground movement. Operating the tow vehicle beneath the aircraft nose section eliminates the additional tractor maneuvering space in front of the airplane. This will be a distinct advantage where nose-in parking is employed. The clearance between the bottom of the nose area and the ground is approximately 10 ft. A 24-ft-long towbar and a 20-ft-long towing vehicle are required.

Some of the larger tow vehicles now in service with the airlines have static drawbar pull capabilities of up to 40,000 lb, which will tow the B-2707 under all but adverse conditions.

Under adverse conditions, two or more tow vehicles are generally used by the airlines for aircraft movement; the B-2707 could be handled in this manner. In addition, larger tow vehicles are now being developed to tow the Air Force C-5A and the Boeing 747 transport. These tow vehicles will also handle the B-2707.

b. Jacking. Provisions for jacking the main and nose landing gear for wheel and tire change are incorporated into the landing gear trucks. Existing 35- to 40-ton alligator-type jacks can be used for tire and wheel change on the nose landing gear and the main landing gear. Figure 3-15 depicts the method in which the landing gear jacks are used.

3.7.2.2 Ground Servicing, Operations
The ground service times and procedures discussed in this section are based on data supplied by American, BOAC, Lufthansa, Pan American, Trans World and United Airlines. Substantiating data has also been obtained by the company's

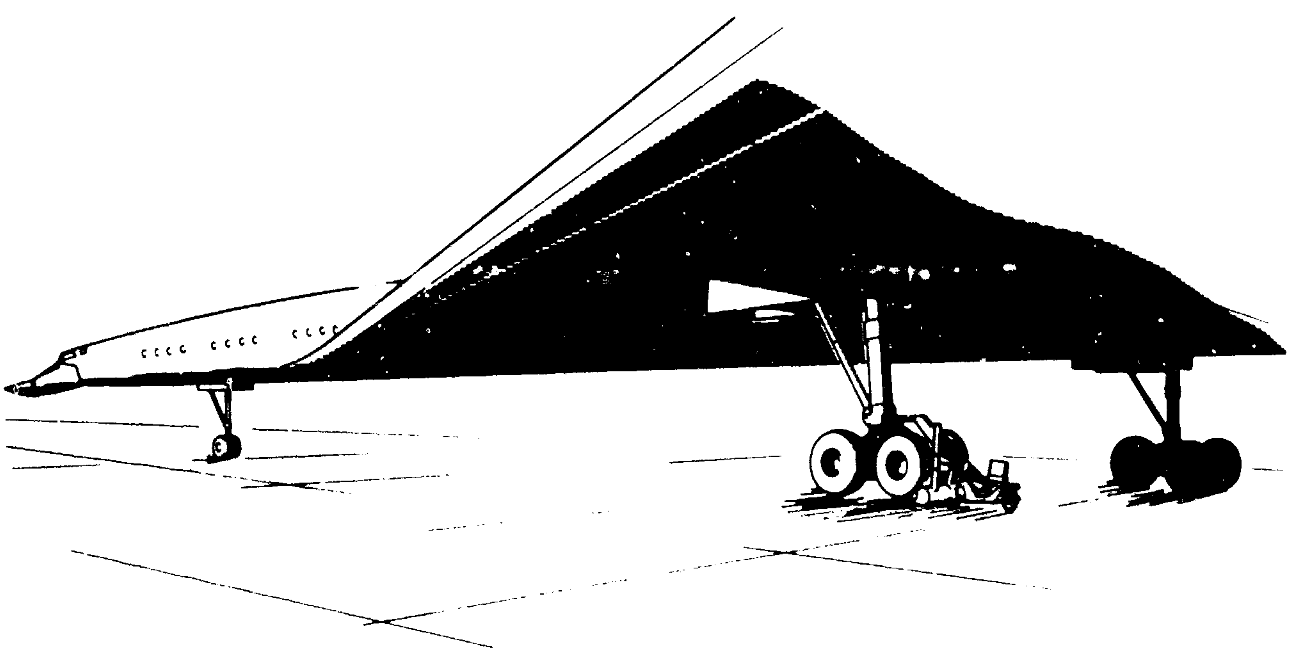


Figure 3-15. Jacking

industrial engineering and product support personnel through actual task-time data gathered during observation of airline terminal operations. The data recently obtained is contained in Ground Service Time and Motion Studies (Ref. 13). The data obtained was evaluated and correlated to B-2707 requirements and the optimum predicted B-2707 service times were developed. The results of analysis of service times are discussed in the following paragraphs:

a. Passenger Loading/Unloading. The B-2707 is compatible with all present systems of passenger loading. The forward-wing position, the number of passenger doors, their size and locations permit loading equipment placement and passenger handling rates equivalent to or better than existing commercial jets. Normal passenger loading and unloading are accomplished through two plug-type doors located on the left side of the airplane (one 32-in. wide and 72-in. high, centered about Body Station 817, and one 42-in. wide and 72-in. high, centered about Body Station 1542). Although passenger loading and unloading are normally conducted through the two forward-entry doors, two other doors, located on the left-hand side of the fuselage (one 42-in. wide and 72-in. high, centered about Body Station 2291, and one 32-in. wide and 72-in. high, centered about Body Station 2961) can be used to facilitate more rapid loading and unloading of passengers. The doors swing inward and then outward and rest against the body in the full-open position. Passenger loading and unloading devices, capable of reaching the 152-in. sill height of the forward-entry door and the 168-in. sill height of the mid-entry door, are required for normal loading operations. Special loading equipment would be required to utilize the two aft doors.

Passenger loading bridges are available in many configurations, such as fixed length and variable length swing types, which are pivot-anchored at the terminal end, and extendable types suspended from rail beams attached to the terminal buildings. All swing-type bridges capable of extending to about 100 ft will be usable for loading the B-2707 at the forward door. Most of the existing bridges of this type will be usable at the mid-entry door, but will require a height extension of 8 in. One method of achieving this height would be to provide a transition ramp at the airplane end of the loading bridge (Fig. 3-16).

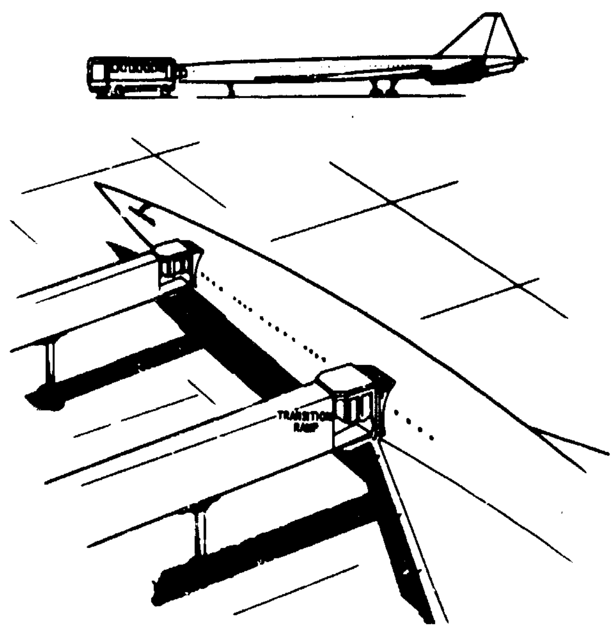


Figure 3-16. Passenger Loading

At John F. Kennedy International Airport, and certain similar air terminals, the presently installed rail beam-mounted bridges used with forward-entry door loading will require modification to be compatible with the B-2707. In these cases, it will be necessary to move the loading bridge farther out from the building to reach the forward-entry door, located approximately 52 ft from the nose of the airplane. At air terminals where a large volume of passengers must be exchanged using the nose loading type facility terminal facilities must be provided to utilize both the forward- and mid-passenger service doors. A detailed discussion of air terminal facilities requirements is contained in Sec. 4.0.

The mobile lounge concept for passenger handling is completely compatible with the B-2707. Self-propelled mobile lounges used at Dulles International Airport, Washington, D.C., are 54-ft long, 16-ft wide, and 17-1/2 ft high, and can reach to a sill height of 150 in. No modification is required for loading through the forward-entry door; however, the transition ramp will require modification for the 168-in. sill height of the mid-entry door.

While these concepts may be applied to B-2707 passenger loading, it is emphasized that the B-2707 is designed to be compatible with all

existing methods, including standard manual or powered passenger staircases of all types now in worldwide use.

In Europe, many airports use apron buses to move passengers from the terminals to the airplane, where the passengers are loaded and unloaded on staircases. Existing staircases can be used at the forward-entry door. Staircases with a higher reach will be required at the mid-entry door.

The average boarding rate through the main forward-entry door is 2-1/2 sec per passenger. The average deplaning time is 2 sec per passenger. The average boarding rate for the main mid-entry door is 2-1/2 sec per passenger, and the deplaning rate is 2 seconds per passenger. Motorized boarding equipment is positioned within 30 seconds, and passengers commence deplaning within 1 minute. Thus, the passenger handling service times, as shown on the composite timelines (Figs. 3-11 and 3-12) for an origin/turnaround station will be 8 minutes to deplane the full 277 passengers and 9.5 minutes to enplane. The passenger loading times for an enroute stop will be 5 minutes for deplaning and 5.75 minutes for enplaning. Figures 3-17 and 3-30 illustrate graphically the procedures and times required for passenger handling. Figure 3-17 is one of several which break down the servicing functions into task and time procedures and compare the present-day subsonic aircraft servicing requirements to the B-2707. (Figures 3-30 through 3-42 illustrate the remaining servicing functions and are located in Par. 3.7.2.4).

b. Baggage/Cargo Handling. Baggage and cargo handling is a significant time consuming task in airline operations. The B-2707 can utilize preloaded containers, if desired by the airline, to reduce the time required to handle the large amounts of baggage and cargo to be transported and to meet the ground operations times as stated in the RFP.

Two large baggage and cargo compartments are provided on the B-2707, one forward in the lower section of the fuselage, with the loading door centered about Body Station 1362; the aft cargo compartment is located immediately aft of the passenger cabin, with the loading door centered about Body Station 3320. Both doors are 50- by 100-in. sliding plug-type doors, located on the bottom of the fuselage.

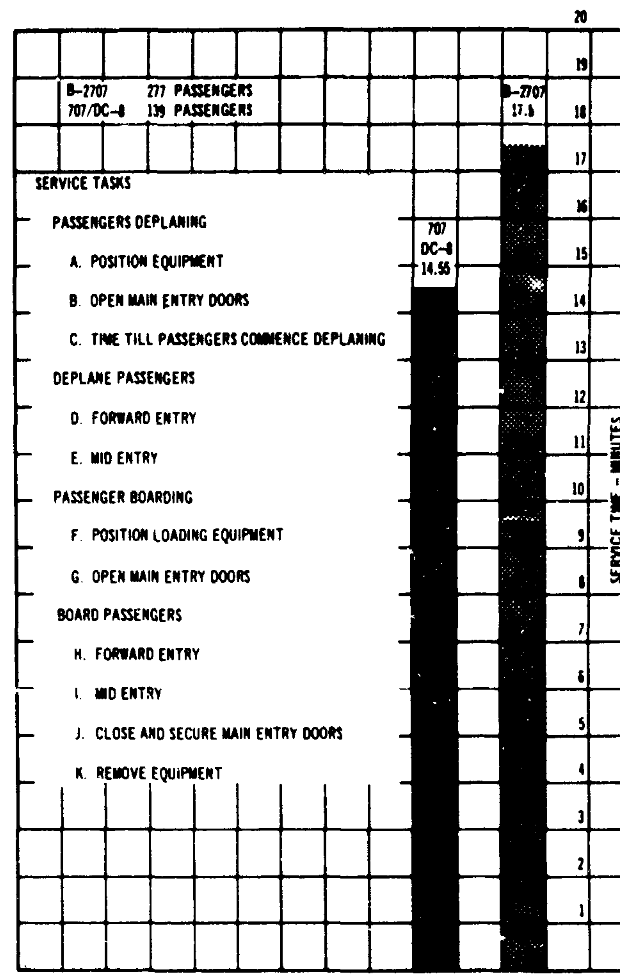


Figure 3-17. Origin/Turnaround Passenger Loading/Unloading

The forward compartment accommodates 1,902 cu ft of bulk or hand-loaded cargo or 1,376 cubic ft in the 16 preloaded cargo containers. The aft compartment accommodates 1,204 cu ft of bulk or hand-loaded cargo or 708 cu ft of cargo in six preloaded containers, plus 140 cu ft of bulk hand-loaded cargo.

Although the baggage/cargo compartments are designed to allow hand loading of baggage and cargo using conventional-type conveyor loading equipment, both compartments have provisions for installation of an integral container loading system, which will allow the ground personnel, working at ground level, to load, stow, and unload the containers (Fig. 3-18). Use of this method of cargo handling will allow 50 percent of

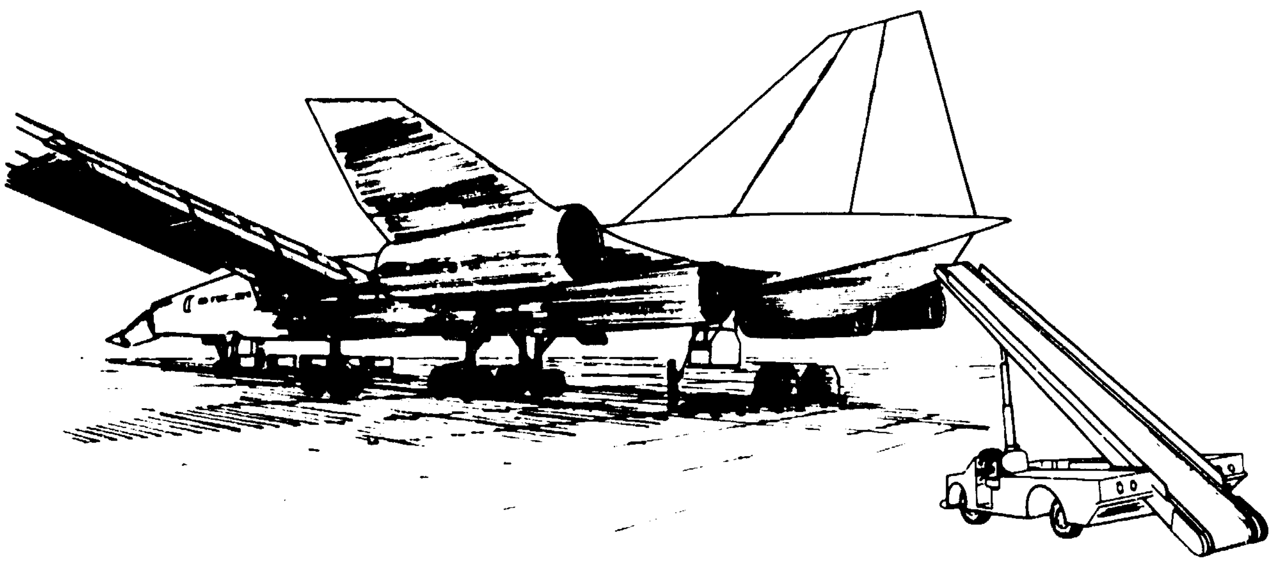


Figure 3-18. Cargo

the baggage/cargo to be exchanged at an enroute station with in 12.4 minutes. One hundred percent of the baggage/cargo can be exchanged at origin/turnaround stations within 23 minutes (Figs. 3-31 through 3-34).

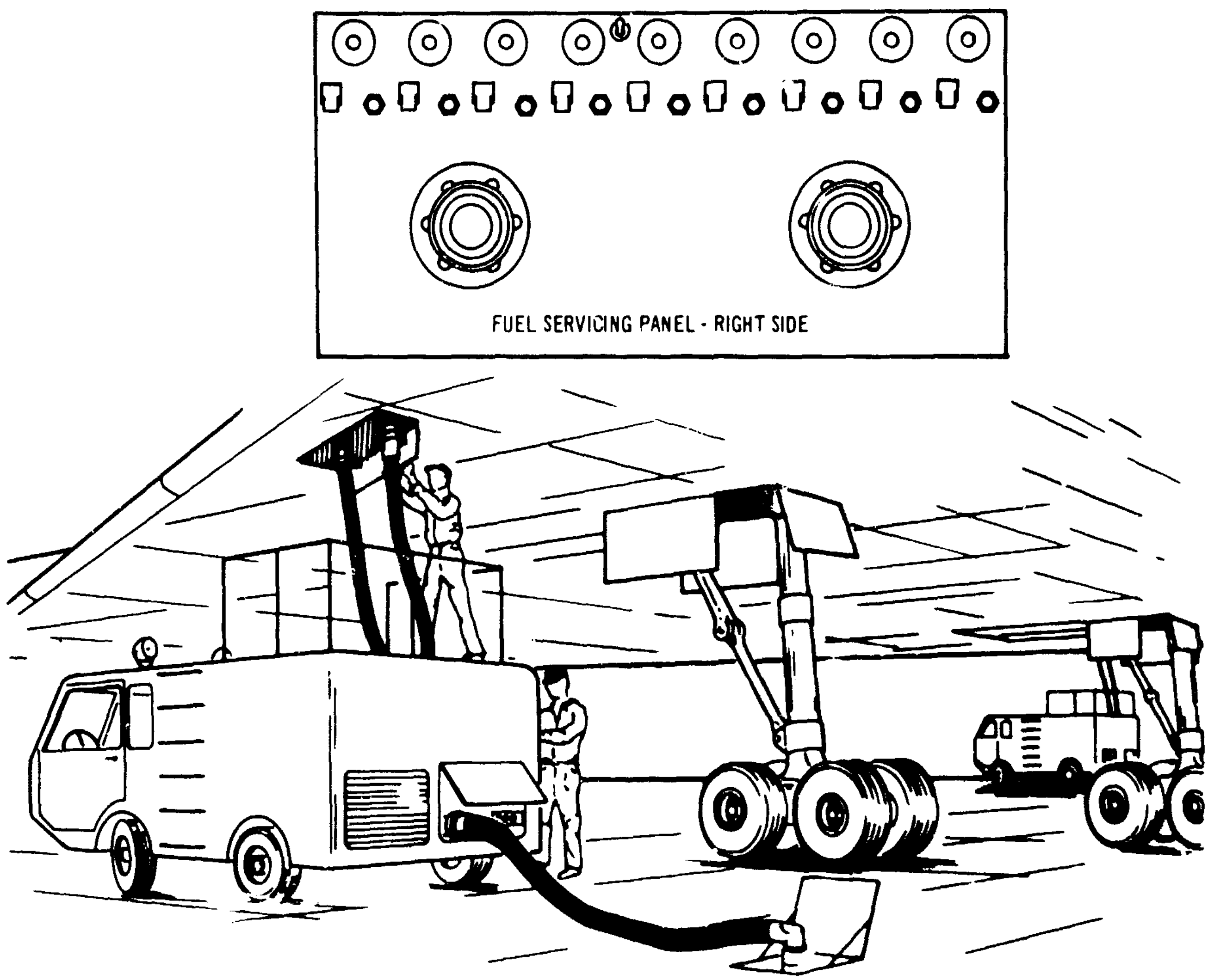
The B-2707 can also be hand-loaded, using conventional ground loading equipment, such as conveyor belt loaders. Although hand-loading is not as fast or as efficient as the containerized loading system, the B-2707 can be hand-loaded at the enroute and origin/turnaround stations and meet the 30- and 90-minute RFP requirement. The hand-loading times are 21 minutes for the enroute station and 38 minutes for the origin/turnaround station.

Hand-loading of the baggage/cargo compartment will extend the total time required for origin/turnaround and enroute servicing to 4'.64 minutes for origin/turnaround and to 24.64 minutes for enroute servicing.

c. Fueling. The maximum usable fuel capacity is 54,790 U.S. gal (367,100 lb) of commercial aviation kerosene. Two illuminated wing fueling stations, located at Body Station 2346, Buttock Line 250, and 11.2 ft above the ground, each having two filler receptacles, are provided for pressure fueling (Fig. 3-19). The right-hand station is equipped with individual fuel tank quantity gages and fuel valve control switches. The system is designed for a fueling pressure of 50 psi and a fill rate of 500 U.S. gpm at each receptacle (1000 gpm at each station, 2000 gpm combined). Fuel vents are provided in the outboard wing and in the aft body tail cone. To supplement the electronic fuel quantity indicating system, a backup fuel quantity gaging system is provided on all tanks.

Fueling requires a mobile or stationary external fuel source and connecting hoses provided with nozzles that mate with the filler adapters. Mating connectors for pressure fueling are the same as used with present 707-727 type airplanes. All present fueling equipment used to service existing jet transports, having the desired flow rates, are capable of fueling the B-2707. In general, a fuel dispensing rate of at least 500 gpm at 50 psi per filler nozzle should be available to keep servicing times to a minimum.

Defueling is accomplished through the pressure refueling receptacles. A manual valve, operable only from the ground, connects the fueling manifold to the engine fuel system to allow use of the boost pumps in defueling. Using the cross-feed manifold, it is possible to defuel to the sump level. The fuel service access panel cannot be closed when the defueling valve is in a position other than the closed position. Approximate defueling rates, using boost pumps, are 150 U.S. gpm per receptacle, or 600 U.S. gpm total. Suction defueling is also possible, using ground equipment.



NO. 1 MAIN	27,800 LB	4,150 GAL	FORWARD AUX	137,000 LB	20,450 GAL
NO. 2 MAIN	27,800 LB	4,150 GAL	AUX NO 1A	50,450 LB	7,530 GAL
NO. 3 MAIN	27,800 LB	4,150 GAL	AUX NO 4A	50,450 LB	7,530 GAL
NO. 4 MAIN	27,800 LB	4,150 GAL	AFT AUX	18,000 LB	2,680 GAL
MAXIMUM USEABLE FUEL			TOTAL	367,100 LBS	54,790 GAL

Figure 3-19. Fuel Service

An example of a time-critical fueling station is the enroute stop at Paris during a Rome-Paris-New York flight. To continue the flight from Paris to New York, approximately 244,000 lb of fuel will be required. The flight distance, corrected for the most critical headwind conditions, is approximately 3,760 statute miles. The maximum fuel load which can be supplied during a 20-minute enroute stop is 179,600 lb. Due to these conditions, either extra fuel must be carried from Rome, or the enroute stop extended to 25 minutes to accomplish the required fueling.

d. Turnaround Fueling. During origin/turnaround servicing 307,100 lb of fuel can be supplied to the B-2707 during the 30-minute stop. For a

maximum usable fuel load, this assumes that 60,000 lb of fuel reserves are already on board. Figures 3-35 and 3-36 depict the service tasks and times required to fuel the B-2707 at origin/turnaround and at enroute stations.

e. Galley Servicing. Four plug-type galley servicing access doors are provided on the right side of the airplane; three are used for normal galley service. The forward galley service access is a 32-in. by 60-in. door, centered about Body Station 846, with a sill height of approximately 152 in. The center galley service access is a 42-in. by 60-in. door, centered about Body Station 1542, with a sill height of approximately 168 in. The aft galley service access is a 32-in. by 60-in. door, centered about Body Station 2961, with a sill height of approximately 210 in. The service doors open outward after an initial inward movement and rest against the fuselage in the full-open position.

Five galley units are provided. One unit is located forward in the first-class section, two units are located in the mid-tourist-class section, and the remaining two units are located at the rear of the tourist-class section. Each galley location is provided with galley service access doors immediately adjacent.

Mobile lift-type loaders presently used by commercial airlines will adequately service the forward and mid-galley locations. At the aft galley location, a new unit of service equipment will be required. These servicing concepts are shown in Fig. 3-20. Trade studies are being conducted to determine the optimum method and equipment needed to service the galleys. These studies will continue to ensure optimum equipment for the production-type airplane.

The B-2707 galley service times, based on an elevated van-type galley service truck is approximately 16 minutes for the enroute stop and 18 minutes for the original turnaround stop, using 2 ground service units (Figs. 3-37 and 3-38).

f. Potable Water Service. One pressurized water supply of approximately 60 U.S. gal, with pressure automatically maintained, is provided for washing, galley, and drinking purposes. The water tank is sized to accept 80 U.S. gal of water, at customer option. The tank is located below the main floor, forward of the nose gear well and is pressurized by air taken from the air-conditioning supply ducting or from a ground pressure source during ground servicing.

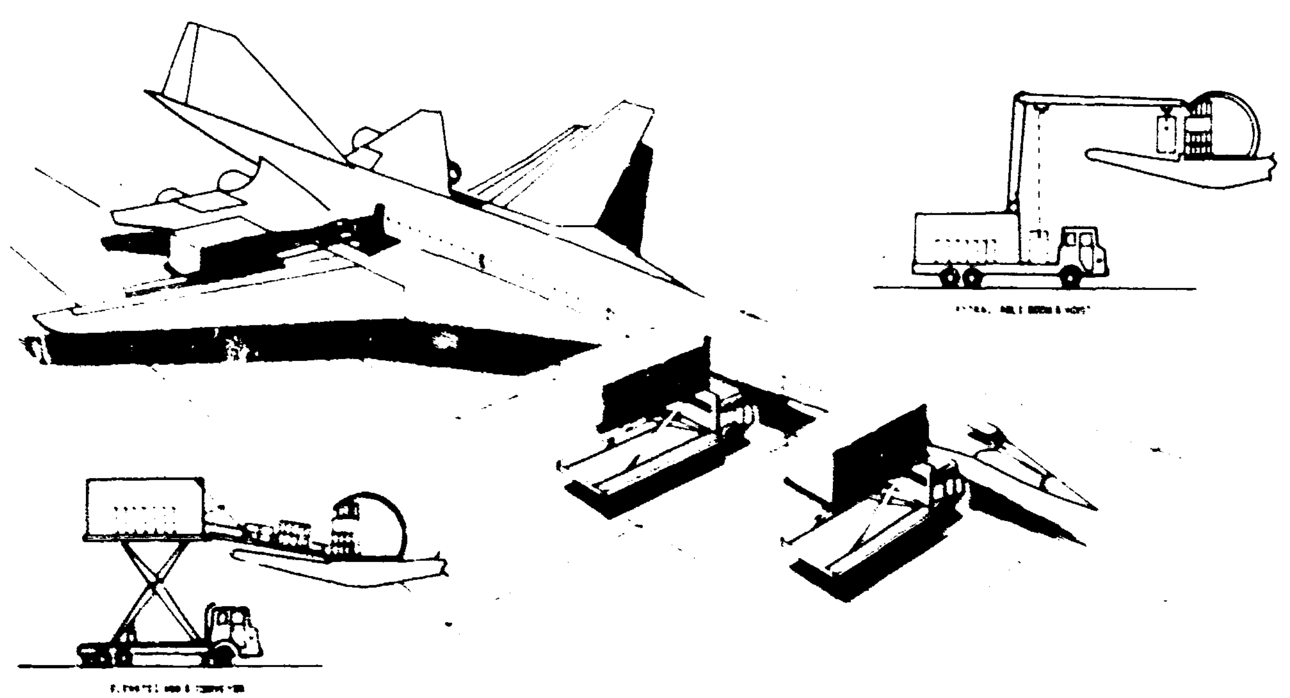


Figure 3-20. Galley Service

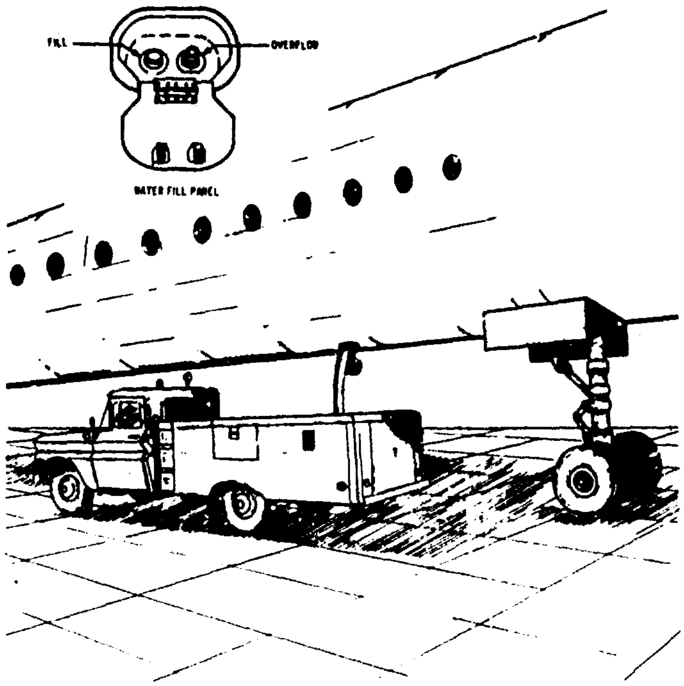


Figure 3-21. Water Service

The water service panel is located in the forward equipment bay, forward of the nose gear well, at a height of approximately 108 in. (Fig. 3-21).

Ground service equipment now in use by the airlines for potable water servicing will satisfy the B-2707 requirements and may be either a permanent water service installation or a mobile unit. Normal ground filling rate is 10 U.S. gpm at 25 psig, using a 3/4-in. fitting. A service stand, integral to the service unit, may be necessary to reach the height of the service panel, depending on the type of service unit used. Required service time to refill the 60 U. S. gal capacity is 9.25 minutes (Fig. 3-30).

During flight operations when low payloads are carried, water ballast is required to maintain the airplane center of gravity within acceptable limits. This water ballast is contained in a 1,380- gal bladder tank in the forward equipment bay. Normal ground filling and draining rates will be 150 gpm and the service time required for the maximum load is 12-1/2 minutes (Fig. 3-22).

g. Toilet Servicing. Six flushing-type toilets are provided: one located in the first-class section of the passenger cabin, centered about Body

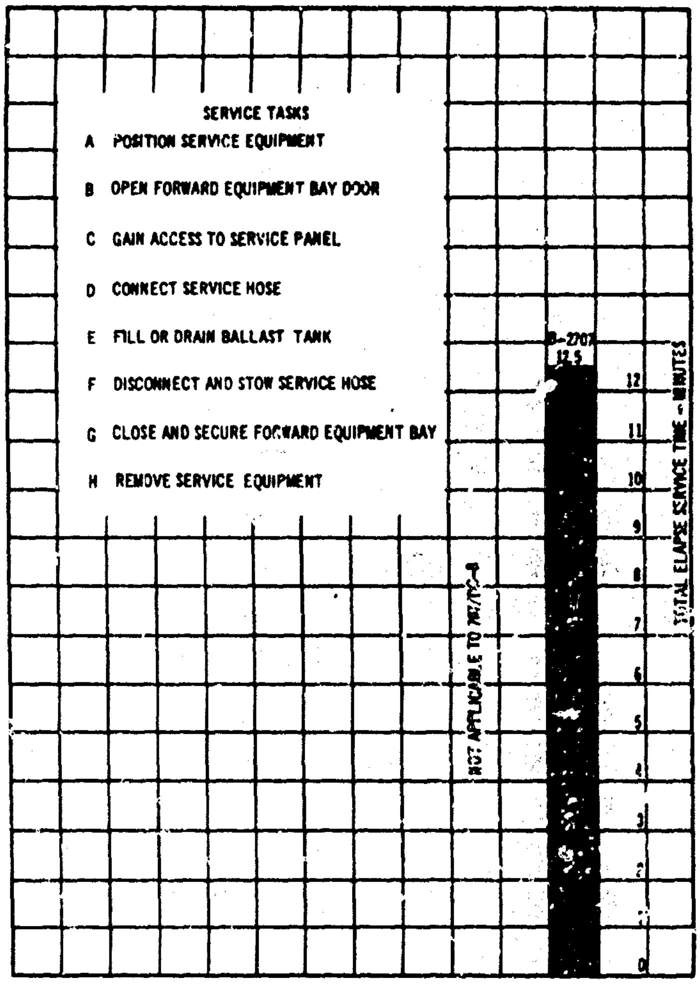


Figure 3-22. Water Ballast

Station 790; three located in the center-cabin section, centered about Body Station 1542; and one aft of the main passenger cabin, centered about Body Station 3000. Each of the toilets has a waste tank of 20 U.S. gal capacity. The three toilet waste tanks in the center location and the two waste tanks in the aft location are manifolded together to provide a single-service point at each location. With these and the front location, three toilet service access panels are provided on the lower surface of the fuselage (Fig. 3-23).

All toilet service connections on the B-2707 are the same as those in use on present Boeing jet transports. The toilets have 4-in. drain outlets. Servicing equipment should have at least a 150 gal waste water tank, a 60 gal flushing water tank, and a 30 gal chemical solution tank. It

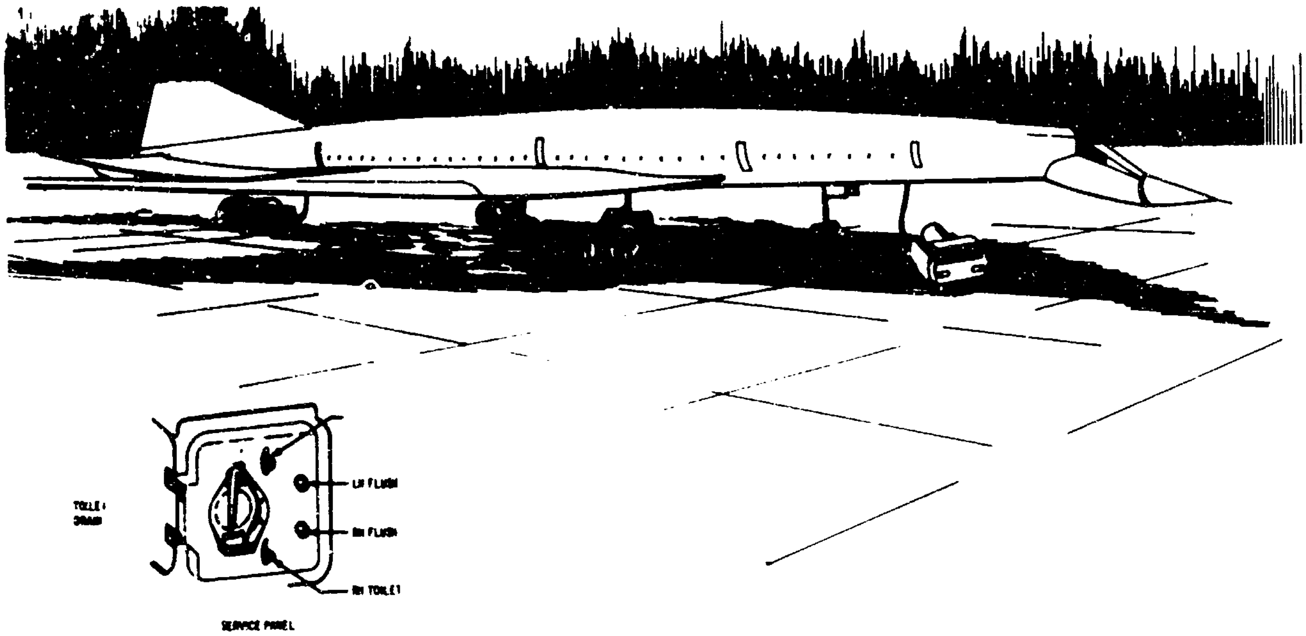


Figure 3-23. Lavatory/Toilet Service

must have a reversible-flow pump system, capable of 15 to 20 gpm at a pressure of 25 psi, and must be equipped with a flow meter for chemical flushing. Each toilet will require three gallons of fresh chemical after each flushing operation. All tanks on the service truck should be equipped with heaters to prevent freezing during extreme low temperature weather operation.

Due to the similarity of the systems, service times and tasks for the B-2707 and subsonic transports are nearly identical. The required toilet service time for the B-2707 is 12.50 minutes (Fig. 3-40).

h. Air-Conditioning. Conditioned air is required immediately after engine shutdown to maintain passenger and flight crew comfort. The ground conditioned air supply source should be capable of maintaining the cabin temperature at a maximum of 85° F, with a full load of passengers on a standard 103° F hot day; or maintain the cabin at a minimum of 75° F, with as few as 60 passengers aboard when the outside air temperature is minus 50° F. Figures 3-24 and 3-25 indicate the heating and cooling requirements for varying ambient conditions. Although extremely large capacity units may be required under extreme conditions, calculations indicate that a refrigeration capacity of 60 to 80 tons and a heating capacity of 600,000 Btu/hour will adequately support the B-2707 under most operating conditions.

Aircraft ground air-conditioning may also be provided using the engine ground start cart to drive the air-cycle machine turbine, which supplies air-conditioning through the on-board environmental control system.

Ground air-conditioning service is not a critical time factor in the service procedure. It requires only one minute to provide connection of the ground unit to the aircraft. A ground air-conditioning service panel is located on the lower portion of the fuselage at approximately Body Station 3020, 158 in. above the ground, and contains an 8-in.-diameter supply duct (Fig. 3-26). Ground air-conditioning equipment now available or in airline inventory will adequately serve the B-2707 for moderate temperature conditions.

i. Ground Interphone Communications. The ground interphone communications system is used to facilitate servicing and coordination of other activities in and around the airplane. External connections are provided at the two electrical equipment bays, in the nose wheel well, at both fueling stations and on each engine nacelle. Existing ground communications equipment used

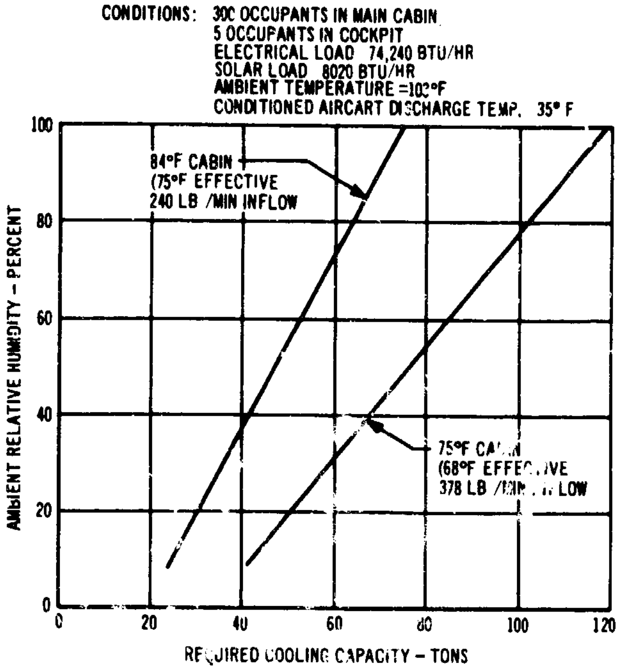


Figure 3–24. Ambient Relative Humidity Versus Ground Cart Cooling Capacity Required to Maintain a Cabin Temperature of 75°F and 85°F

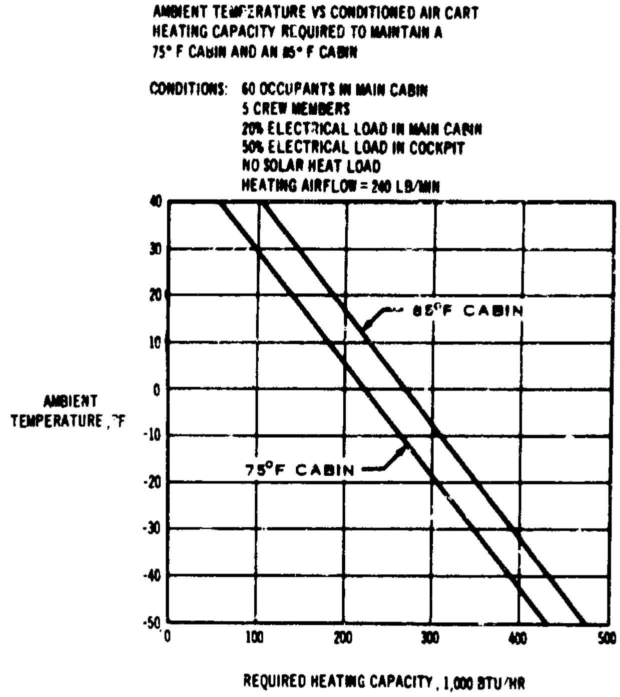


Figure 3–25. Heating Requirements for Maintaining Cabin Temperature

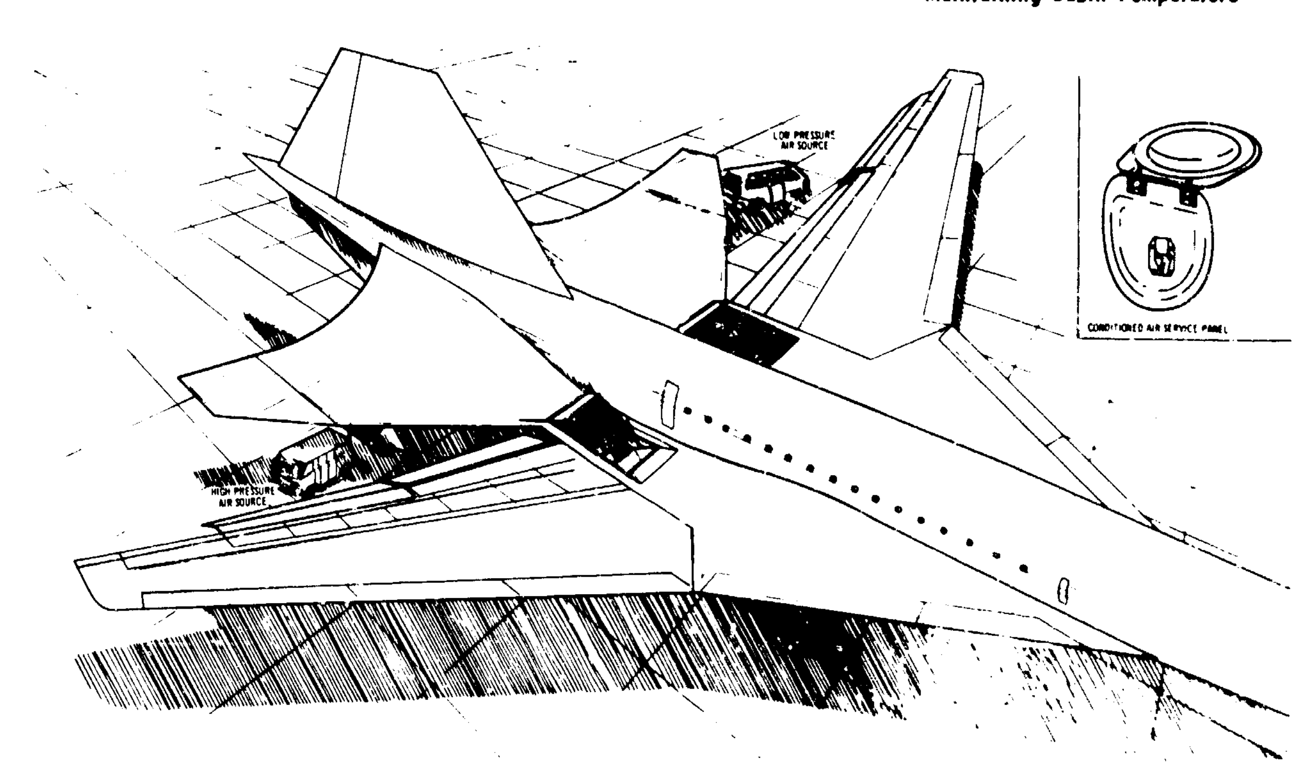


Figure 3–26. Air–Conditioning

on present jet transports will be compatible with the B-2707.

j. Ground Electrical Power. Ground electrical power is another ground service required to permit performance of the ground service functions, and is not, itself, time critical. Ground electrical power is required continuously from just prior to engine shutdown to just after engine startup.

A 60 kva external power receptacle is provided in the nose gear wheel well for ground operations (Fig. 3-27). Power requirements for the B-2707 are 115/200 volts, 3-phase, 400 cps ac. Direct current is supplied by six airplane-installed 28 volt, 75 ampere transformer/rectifiers or by an external source. Electrical load analysis, as contained in the Systems Report, Part A, V2-B2707-10, indicates that the maximum ground power required will be 30 kva.

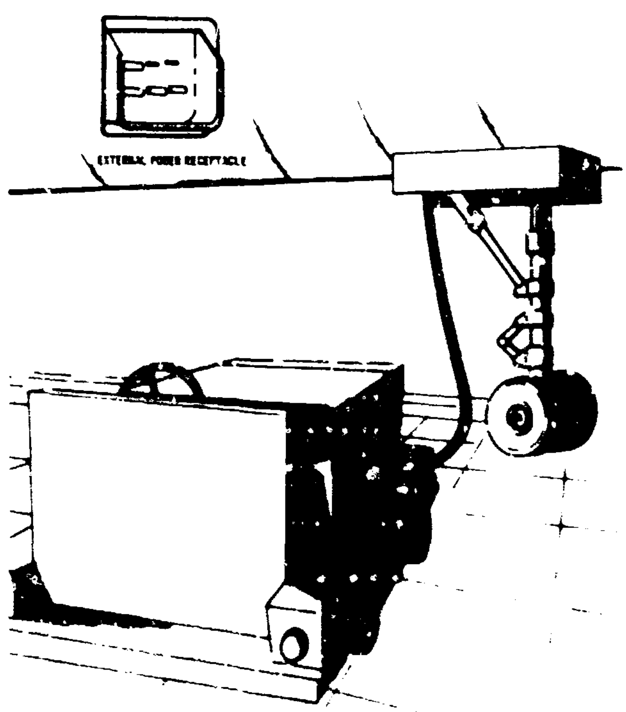


Figure 3-27. Ground Electrical Power

Ground service panels and connectors will be similar to those in existing commercial jet transports, and existing ground power units will adequately service the B-2707. The mating fitting on the GSE unit will be an AN3430 connector and cable to connect to the AN3114-1B receptacle. Mobile and stationary power sources with ratings of 60 to 140 kva, now in use by the airlines, can be used for B-2707 electrical support.

Electrical ground power can also be obtained by operating an on-board generator (through the ADS) by using a ground air cart.

k. Cleaning. At origin/turnaround terminals, cabin and cockpit cleaning and servicing are required, as opposed to the enroute servicing, where only minor cabin pickup and straightening are performed by the flight attendants. At an origin/turnaround, the entire cabin and cockpit are cleaned and serviced by ground service personnel. Interior cabin and flight-deck cleaning methods are similar to those now used on existing jet transports. Electrical outlets are provided in the cabin sidewall.

At the origin/turnaround station, interior cabin cleaning is one of the time-critical services performed. To accomplish the 30-minute service time, the cleaning crew in the first class and forward-tourist compartment should begin their cleaning services immediately after the passengers in these compartments deplane. Upon completion of cleaning and servicing of the forward compartment, the forward cleaning crew augments the aft cleaning crew to complete interior cleaning. The total elapsed cleaning time required is 13.5 minutes. Figure 3-41 details the cleaning and servicing tasks and times required.

l. Engine Starting. A ground source of pneumatic power is required to start the engines of the B-2707. The engines are started by pneumatic starters mounted on the accessory drives. The ground air source connection is located on the lower righthand side of the No. 4 engine nacelle (Fig. 3-28). After starting the No. 4 engine, this engine can be used to start the other engines, or the remaining engines may be started using the ground cart. A ground air source at 50 psia and 254 lb per minute flow rate is required to achieve a desired ground starting time of approximately 30 seconds per engine under all anticipated ambient conditions.

The high pressure air sources currently being used for jet transport engines will start the B-2707 engines, but with longer starting times. Two of these units operating in parallel, or a new unit providing the required flows and pressures (Table 3-A) reduces the starting time

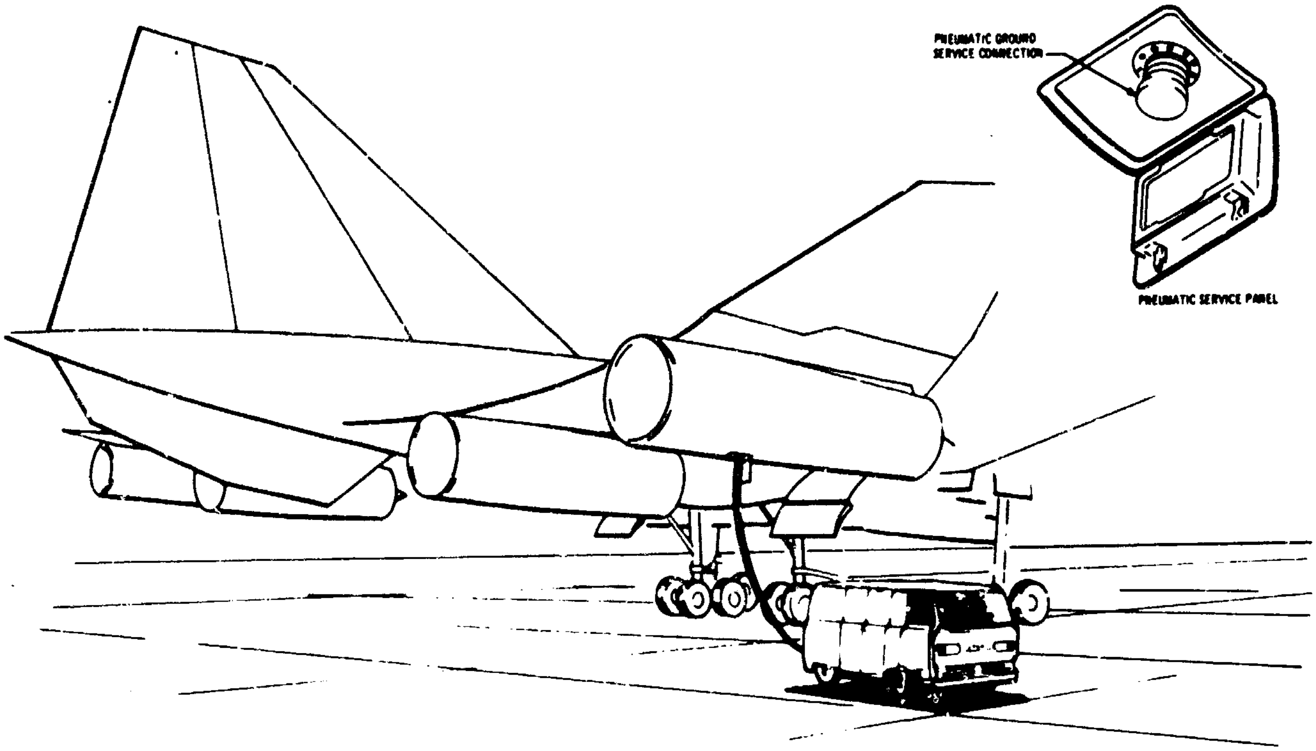


Figure 3-28. Engine Starting

to approximately 30 seconds. Total engine starting time is approximately 4.64 minutes, as shown in Fig. 3-42.

Table 3-A. Engine Starting Requirements—30-Second Start

Starting Data	59°F	125°F	-50°F
Inlet pressure, psia	50.5	46	52.2
Inlet temperature, °F	374	437	268
Air flow, lb per min	254	224	281
Time to start, sec	28.8	34.8	26.5
Time to engine idle	29.9	36.2	27.0

The engine starting cart can also be used to supply aircraft air-conditioning by driving the air-cycle machine turbine, as described in the environmental control section of Systems Report, Part A, V2-B2707-10.

All of the GSE discussed herein is covered in more detail in the GSE Requirements Specification, DSA10180-1.

3.7.2.3 Residual Heat Considerations
Accurate heat transfer analysis is essential both to the design of the B-2707 and to the understanding of potential operational problems. The company's predictions, based on theories verified and corrected by laboratory tests, indicate near ambient temperatures will exist in areas requiring normal ramp servicing. Exterior access panel temperatures will be approximately 100°F. Heavier supporting structure around access panels may reach temperatures of 100 to 130°F (Fig. 3-29), but will pose no problem for ground service personnel. Some heavy structure areas will become progressively warmer over a series of flights and reach ground temperature levels of approximately 160 to 170°F. Also, some small compartments in the wing containing hydraulic actuators may have temperatures as high as 200°F shortly after landing. Such compartments are, however, too small to enter. Normally

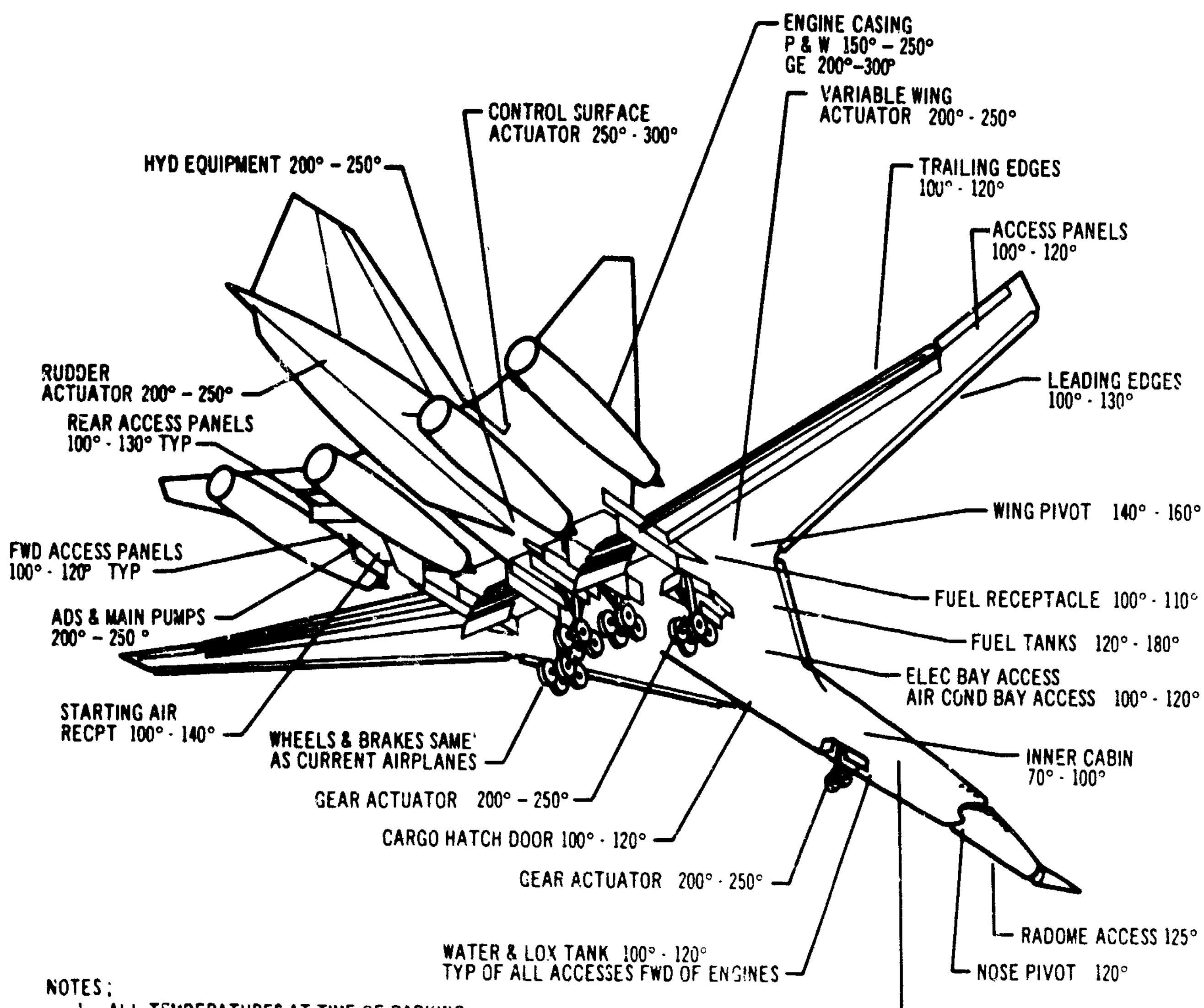


Figure 3–29. Residual Heat Temperatures

origin/turnaround and enroute service will not be affected by such areas except when unscheduled maintenance is required. In these cases, it may be necessary to provide auxiliary cooling to permit rapid access, inspection, and replacement within ground times necessary to achieve an economical maintenance operation.

3.7.2.4 Service Time Comparisons

The individual time charts in this section (Figs. 3-30 through 3-42) are used to compare the B-2707 servicing functions with present day jet transports. The times shown for the B-2707 are those used to form the composite servicing timelines (Figs. 3-11 and 3-12). The data used in these studies is based on information supplied by airlines and is contained in Ref. 13.

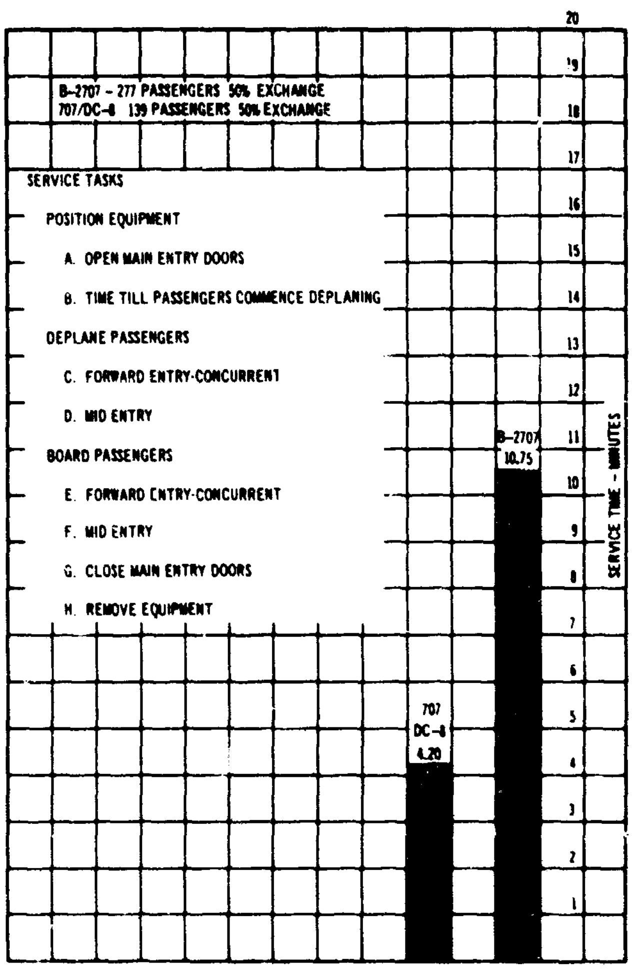


Figure 3-30. Enroute Passenger Loading/Unloading

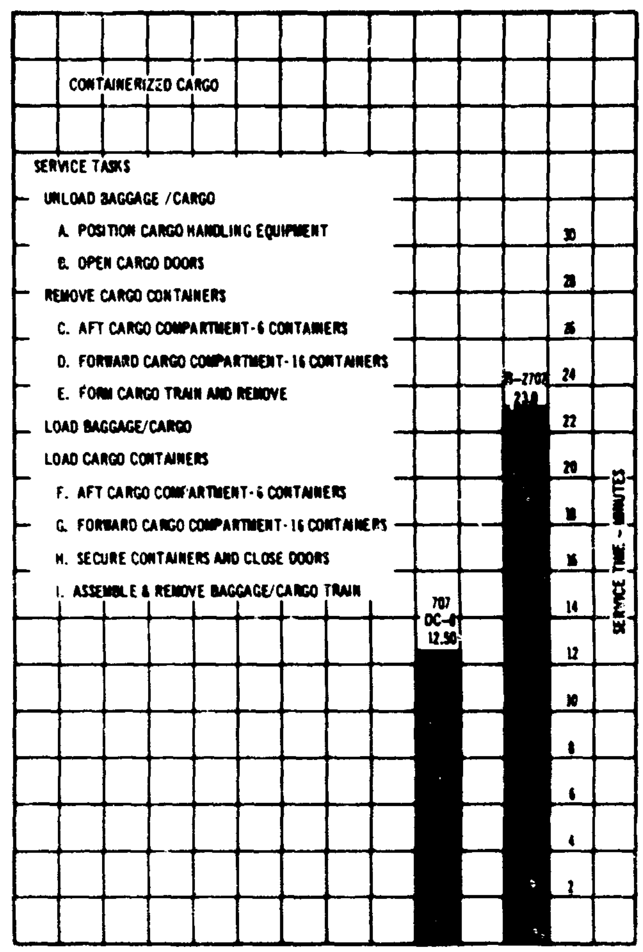


Figure 3-31. Origin/Turnaround Baggage/Cargo Service
(Containerized Cargo)

V4-B2707-1

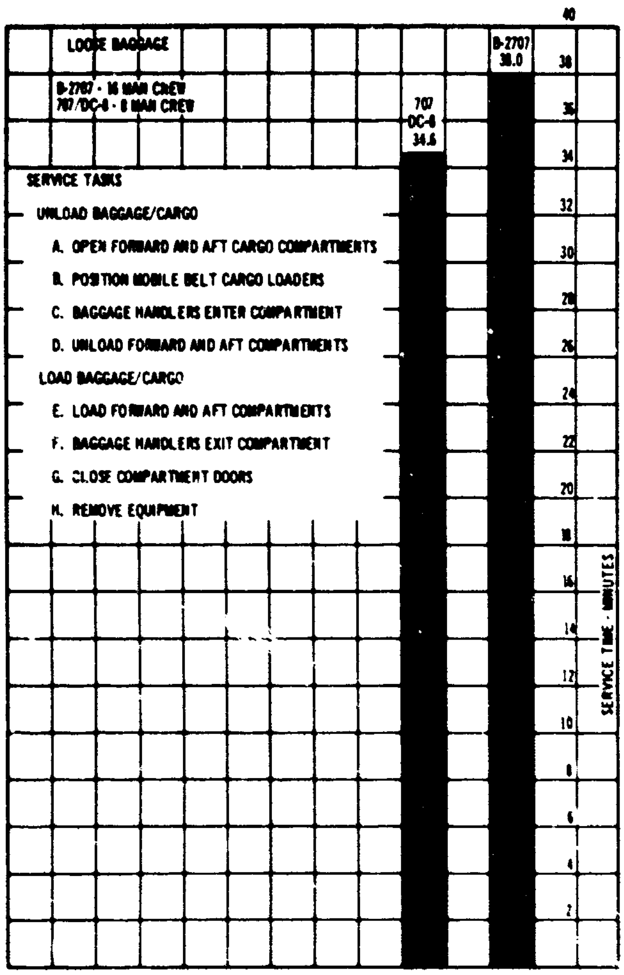


Figure 3-32. Orgin/Turnaround/Cargo Service (Loose Baggage)

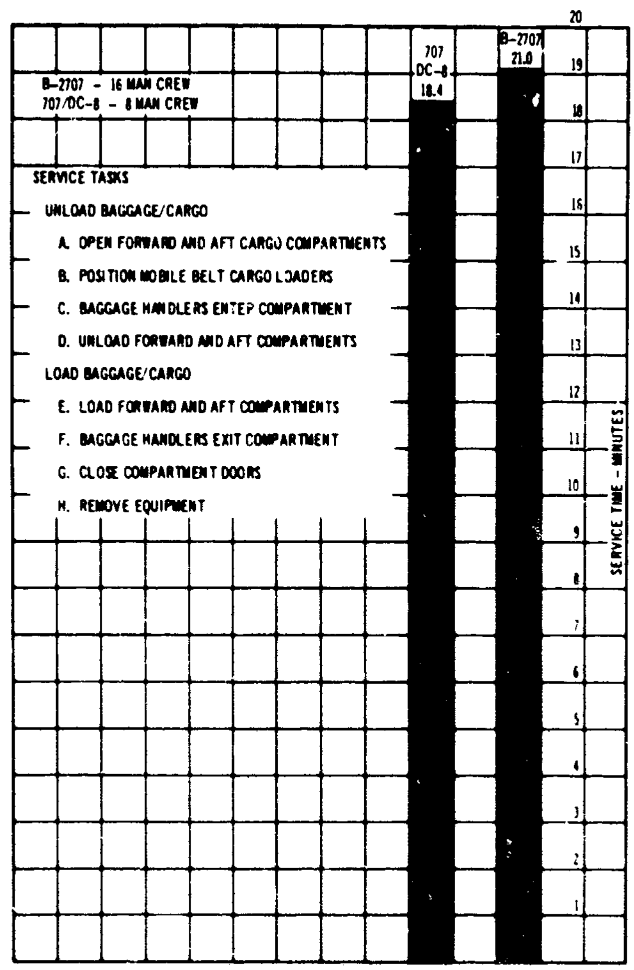


Figure 3-33. Enroute Baggage/Cargo Service (Loose Baggage)

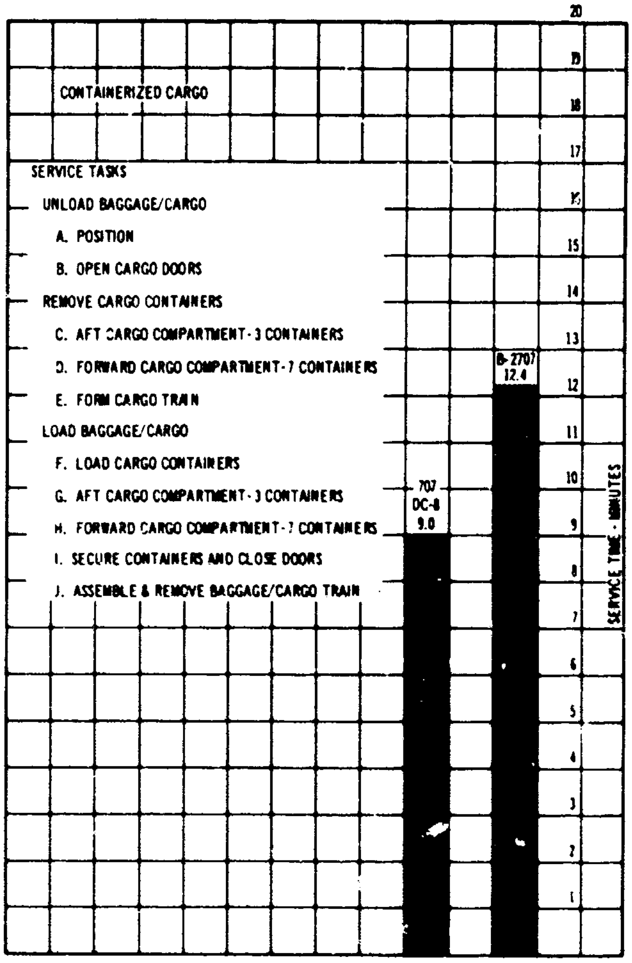


Figure 3-34. Enroute Baggage/Cargo Service (Containerized)

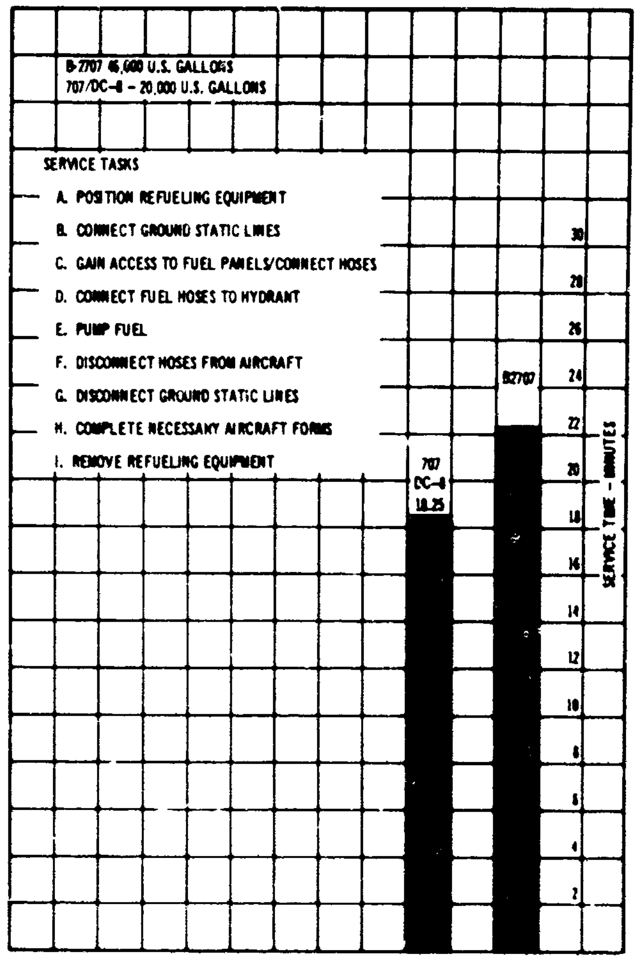


Figure 3-35. Origin/Turnaround Refueling

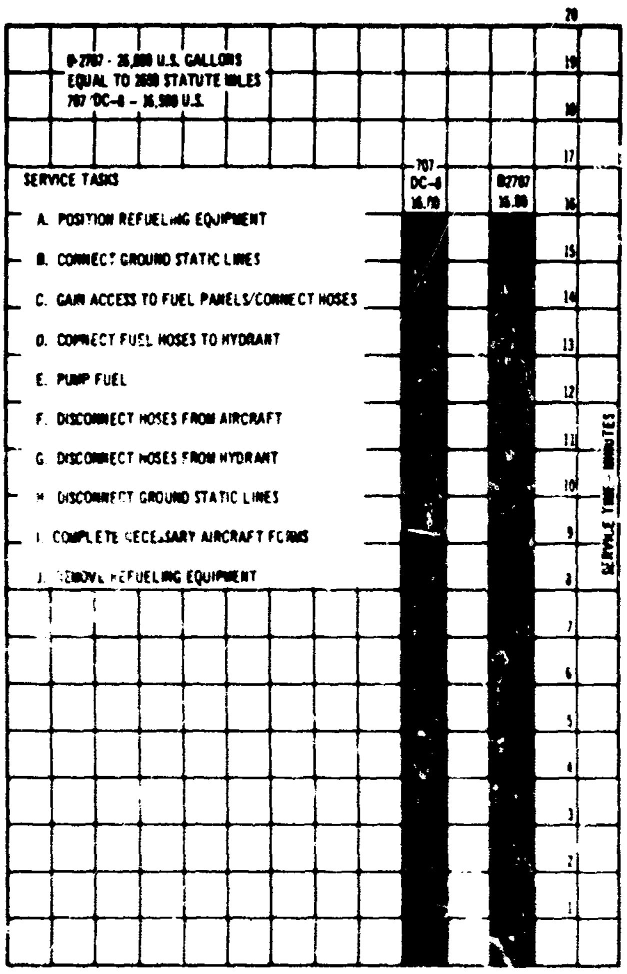


Figure · · ·route Refueling

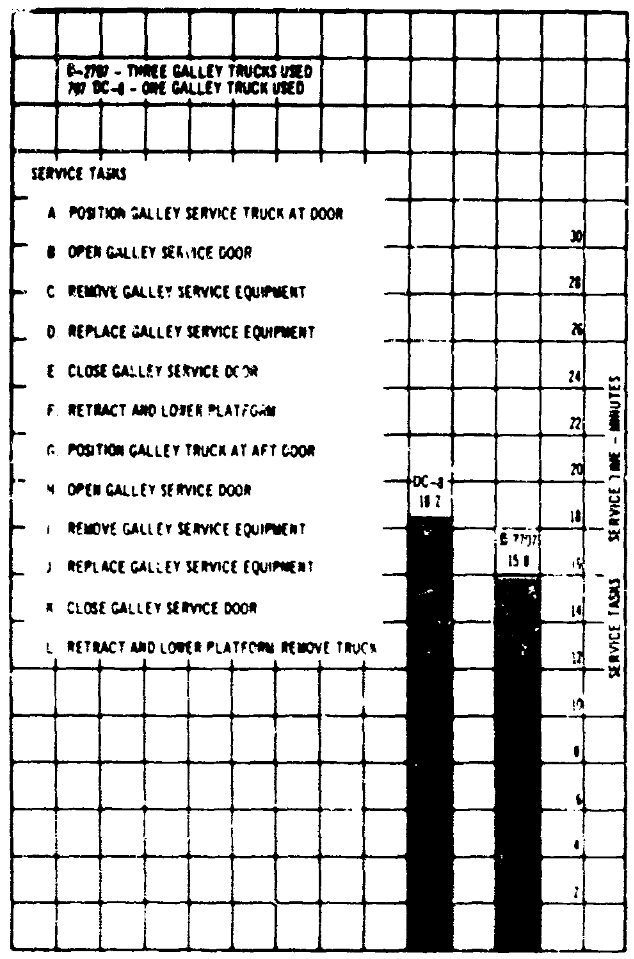


Figure 3-37. Enroute Galley Service

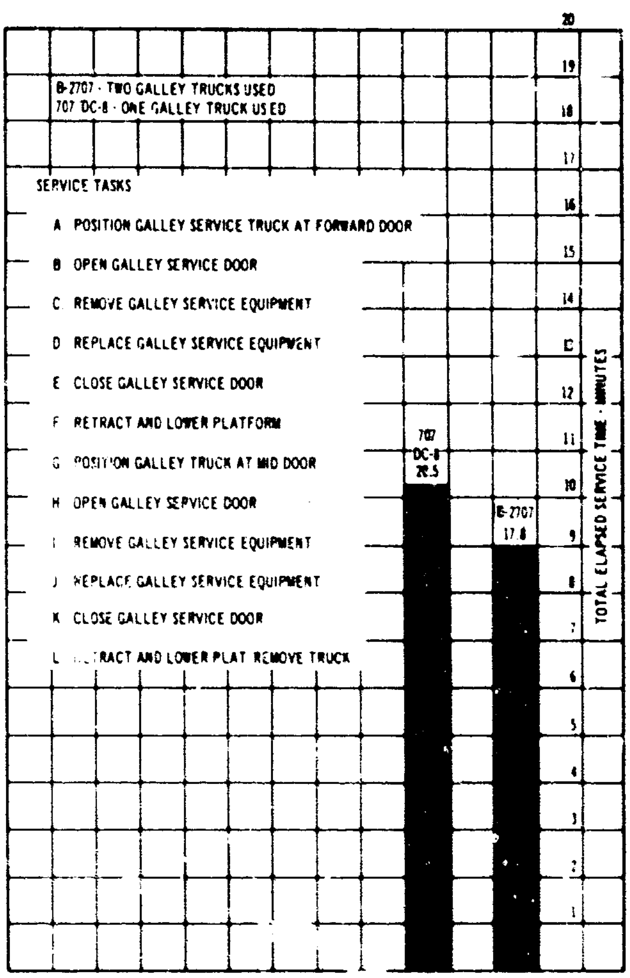


Figure 3-38. Origin Turnaround Galley Service

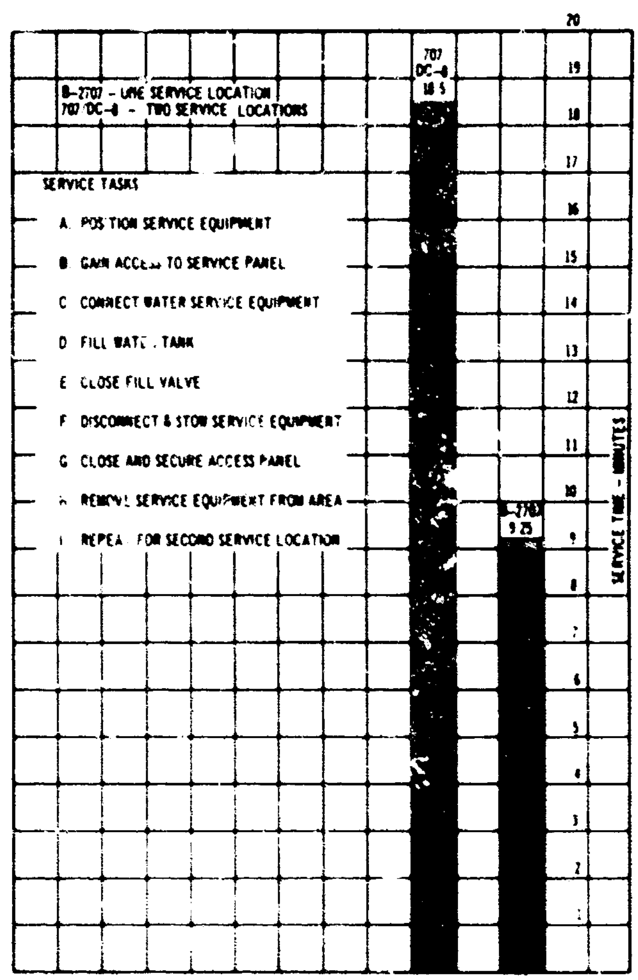


Figure 3-39. Water Service

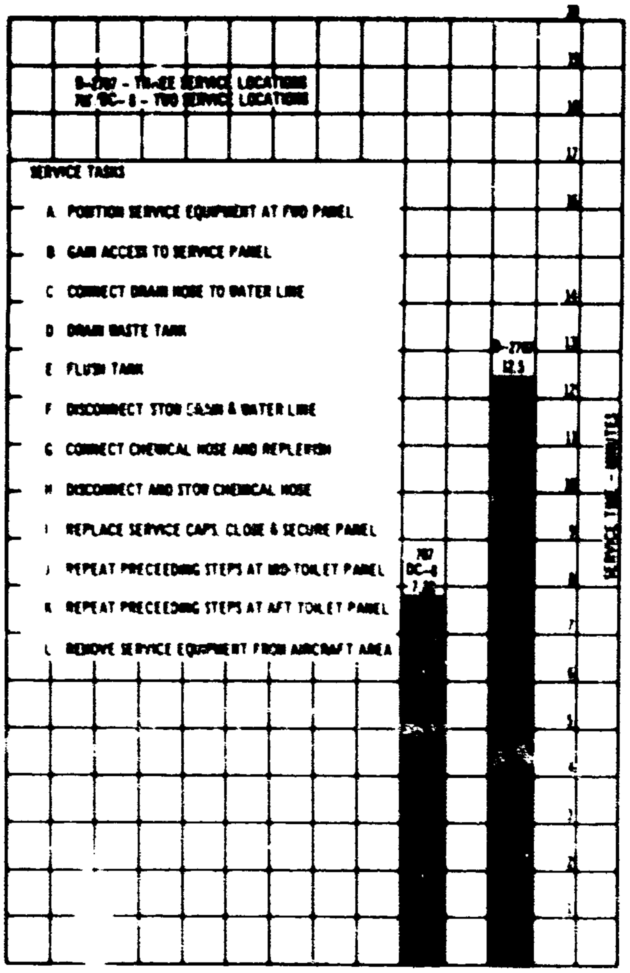


Figure 3-40. Lavatory Toilet Service

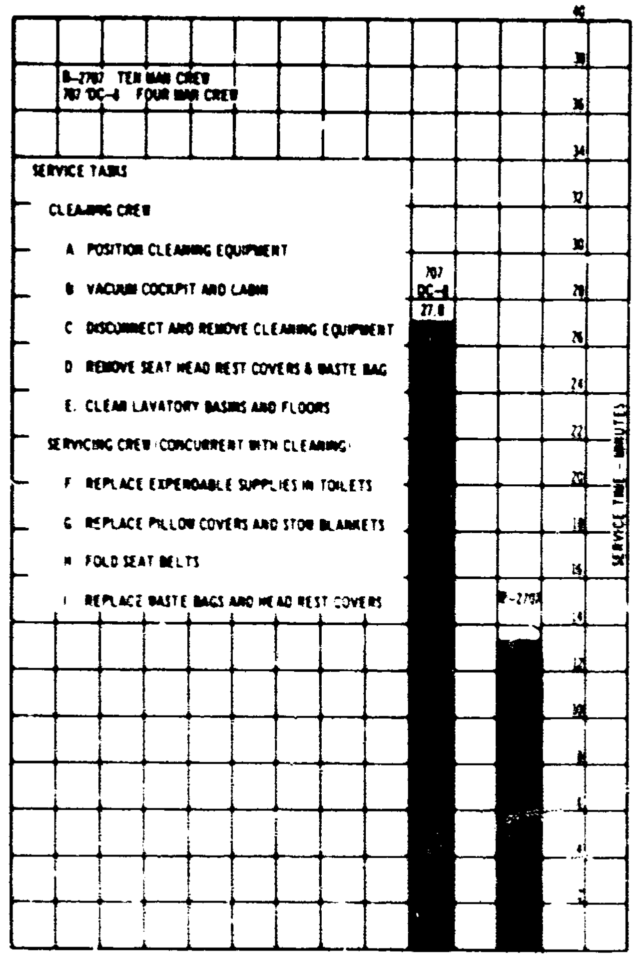


Figure 3-41. Origin Turnaround Interior Cleaning and Servicing

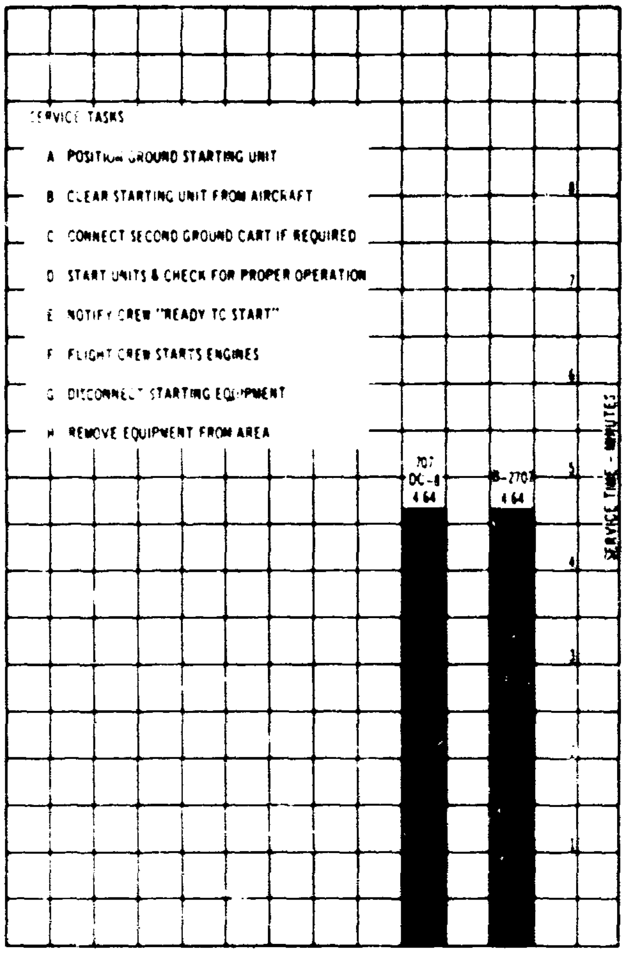


Figure 3-42. Engine Starting

3.7.3 Maintenance

Boeing jet transports have been des… ed with the objective that any individual mainte… e task can be accomplished in 8 hours downti… This same objective has been applied to the B-… 7, thus allowing a flexible maintenan… pro… m, adaptable to the many divergent ope… ation… requirements of domestic and intercontinen… airlines.

The Maintenance Plan for the B-270… based on proven and tested concepts of the ai… industry. These concepts are as follows:

- Determination of security and c… tion of aircraft hardware is accomplish… visual checks, repeated at scheduled i… rvals. The intensity of visual checks varies … th aircraft flight hours.
- Operational checks of aircraft s… ms used in normal day-to-day flight are … conducted at scheduled intervals.
- Functional checks of systems to … rmine that they are performing within … limits are conducted at scheduled inter… s.
- Servicing, including lubrication, … ter checks, replenishing of fluids, … nducted at scheduled intervals.

B-2707 MAINTENANCE PLAN	
LINE	BASE
	AIRFRAME OVERHAUL
DAILY CHECK	BASIC CHECK
	● STRUCTURAL INSPECTION PROG…
INTERMEDIATE CHECK	● COMPONENT OVERHAUL PROGR…
	SHOP OVERHAUL
PERIODIC CHECK	ENGINE
	AIRBORNE ACCESSORIES

Figure 3-43. Line and Base Maintenance

- Visual check of structural integrity is accomplished in conjunction with routine security and condition check of hardware at scheduled intervals.
- Thorough inspection of structural integrity is accomplished at scheduled intervals. Nondestructive inspection techniques are used where feasible. The B-2707 Structural Inspection Program calls out specific structures for inspection and their inspection intervals.
- On-condition component overhaul is based on maintaining a unit in a continuous airworthy condition by routine checks, inspections, services, and tests. The B-2707 Component Overhaul Program identifies component classified "on condition" and specifies requirements to maintain that status.
- Sampling techniques are used where feasible as a means of determining structural integrity and component condition.

The Maintainability Program, V4-B2707-15, will ensure that features are incorporated in the design of the airplane to facilitate maintenance according to these concepts. Airplane features enhancing maintenance are described in Airframe Design Report, Part B, V2-B2707-6-2, Systems Reports, V2-B2707-10 and V2-B2707-11, and Propulsion Reports, V2-B2707-12 and V2-B2707-13.

B-2707 line maintenance is defined as all maintenance work performed on the airplane between overhaul base visits. This includes all scheduled checks controlled by airplane flight hours to maintain the airframe and systems in a continuous, safe operating condition, and the correction of discrepancies, based on pilot's report and ground inspection findings.

B-2707 base maintenance is defined as all maintenance work performed on the airplane during a scheduled visit to a maintenance base and the overhaul of engines and airplane accessories in the shops. This maintenance performed on the airplane is sometimes called a basic check or airframe overhaul.

Figure 3-43 shows how B-2707 line and base maintenance activities are divided. The selection of check time intervals and the plan of escalation from initial to higher time intervals are determined by the FAA Maintenance Review Board and the airline maintenance and engineering organizations. Phase I Document M-III, Sec. 3.0 describes the process. The schedule intervals in flight hours for the checks on Figs. 3-44, 3-45, 3-46, and 3-50 show the ranges where initial starting times could be selected.

Development of the basic B-2707 maintenance planning data, consisting of the scheduled checks, structural inspection program, and component overhaul program, by the Boeing maintenance engineering organization is described in the Product Support Program, V4-B2707-20.

3.7.3.1 Line Maintenance

a. Scheduled Maintenance. Enroute service and turnaround service is not included in the line maintenance program (Par. 3.7.2).

The scheduled line maintenance program for the B-2707 consists of three levels of checks: daily check, intermediate check, and periodic check, performed repetitively at progressively higher airplane flight hours. The work contents of these checks are shown in Figs. 3-44, 3-45, and 3-46 and are designed to allow a continuous auditing of the airframe and systems. Each check is treated individually as a work package. The work requirements of a lower check are either repeated or accomplished in conjunction with a more detailed requirement in the next higher check.

The ground elapsed time goals for the daily, intermediate, and periodic checks are 1, 4 and 16 hours respectively. When the flight schedule of an airline does not allow a 16-hour layover, a partial progressive program can be utilized by dividing the periodic check work content into smaller work packages and accomplishing them with the intermediate checks. Figure 3-47 is an illustration of this work division.

The major work zones of the B-2707 are shown on Fig. 3-48. Between the engines on the left and the right horizontal stabilizer, there is an area of possible work congestion. However, this can be avoided by attention to work scheduling.

Figure 3-49 shows a B-2707 opened up for a periodic check. Convenient access to the work zones is ensured by the following:

- Plug-type doors are provided in all equipment compartments in the fuselage.

STANDARD PROGRAM (BLOCK MAINTENANCE CONCEPT)

DAILY CHECK

GROUND ELAPSED TIME GAOL: 1 HOUR
SCHEDULE INTERVAL: DAILY – 50 FLIGHT HOURS

SCHEDULED WORK – MAJOR TASKS

1. WALK – AROUND CHECK
   - ENGINE INLET AND EXHAUST
   - LANDING GEAR AND WHEEL WELLS (1)
   - CONTROL SURFACES
   - FUEL LEAKS
2. EQUIPMENT CHECK
   - SEATS
   - EMERGENCY EQUIPMENT
3. SERVICING
   - ENGINE OIL (2)
   - HYDRAULIC FLUID (3)
   - OXYGEN (4)
   - ADS OIL (5)

UNSCHEDULED WORK

1. PILOTS REPORTS
2. INSPECTOR WRITE-UPS

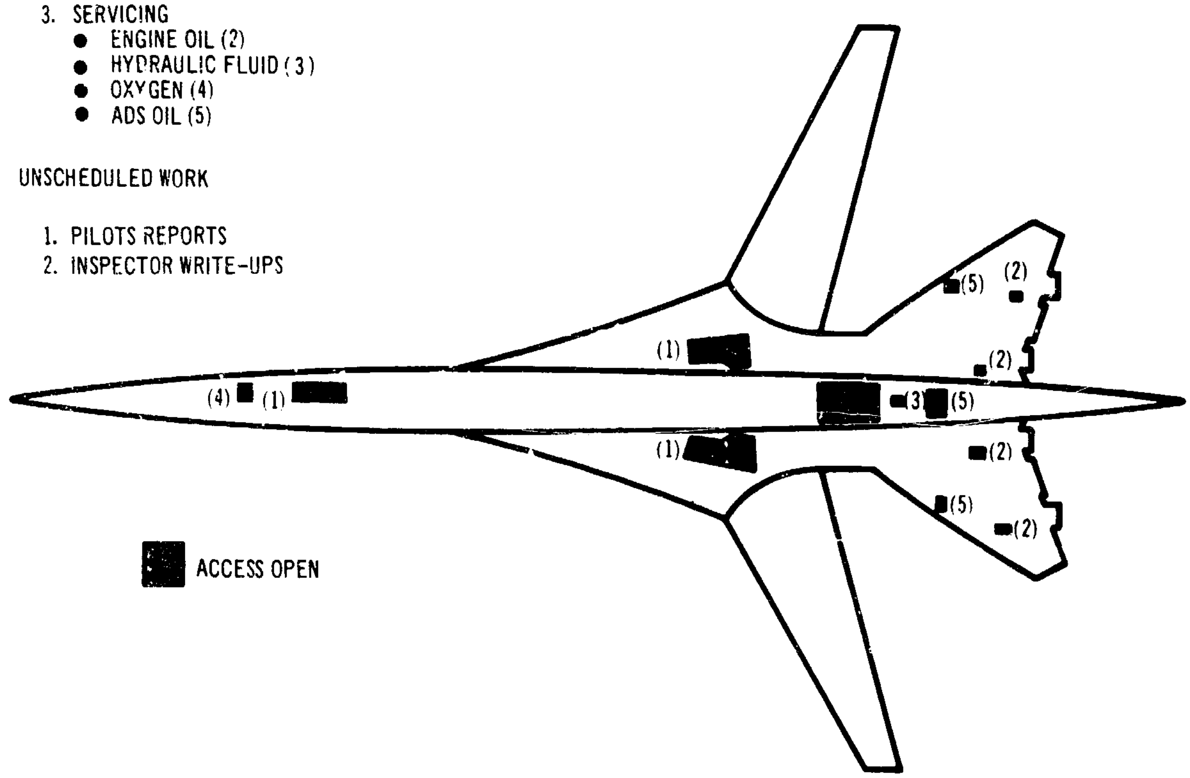


Figure 3–44. Line Maintenance – Daily Check

V4-B2707-1

STANDARD PROGRAM (BLOCK MAINTENANCE CONCEPT)

INTERMEDIATE CHECK

GROUND ELAPSED TIME GOAL: 4 HOURS
SCHEDULE INTERVAL: 75–300 FLIGHT HOURS

SCHEDULED WORK – MAJOR TASKS

1. PRE-SERVICE OPEN UP
2. VISUAL EXTERIOR CHECK – FUSELAGE, EMPENNAGE, WINGS
   - ENGINES (1)
   - RAM AIR INLETS
   - LANDING GEAR AND WHEEL WELLS (2)
   - WING PIVOT (3)
   - CONTROL SURFACES
   - MOVABLE FOREBODY
3. VISUAL INTERIOR CHECK
   - LAVATORIES
   - FLIGHT DECK
   - PASSENGER CABIN
   - GALLEYS
   - CARGO COMPARTMENTS
4. OPERATIONAL CHECKS
   COMMUNICATIONS EQUIPMENT
5. EQUIPMENT CHECK
   EMERGENCY EQUIPMENT
6. SERVICING
   - ENGINE OIL (1)
   - HYDRAULIC FLUID (4)
   - ADS OIL (5)
   - BOOST COMPRESSOR OIL (5)
   - AIRCYCLE MACHINE OIL (6)
   - OXYGEN (7)
7. POST SERVICE CLOSE-UP

UNSCHEDULED WORK
1. PILOT'S REPORTS
2. INSPECTOR WRITE-UPS

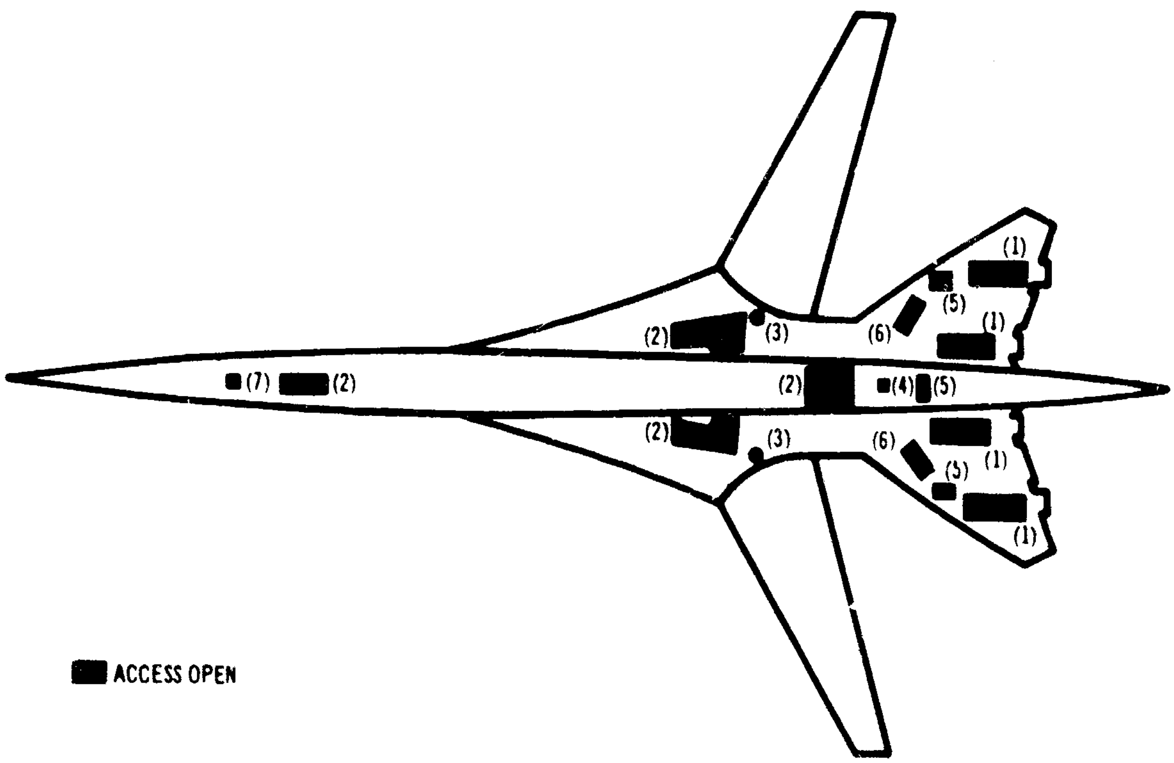


Figure 3–45. Line Maintenance – Intermediate Check

STANDARD PROGRAM (BLOCK MAINTENANCE CONCEPT)

PERIODIC CHECK	GROUND ELAPSED TIME GOAL: SCHEDULE INTERVAL:	16 HOURS 300 – 1,200 FLIGHT HOURS

SCHEDULED WORK – MAJOR TASKS

1. PRESERVICE OPEN UP
2. AREA INSPECTIONS
   - INTERIOR COMPARTMENTS – FLIGHT DECK, PASSENGER CABIN, LAVATORIES, GALLEYS, CARGO COMPARTMENTS
   - AIRCRAFT EQUIPMENT COMPARTMENTS _ FORE AND AFT ELECTRONICS BAY, AIR CONDITIONING DISTRIBUTION AND ELECTRICAL EQUIPMENT BAY, CONTROL SYSTEM BAY, HYDRAULIC EQUIPMENT BAY, ADS BAY, MOVABLE FOREBODY CONTROLS BAY
   - WING AREAS – WING PIVOT, LEADING EDGE, TRAILING EDGE
   - EMPENNAGE AREAS – AIR CONDITIONING PACK BAY, ADS BAY, ELEVATOR AND ELEVON CONTROLS BAY, RUDDER CONTROLS BAY
   - WHEEL WELL AREAS – NOSE GEAR ASSEMBLY, MAIN GEAR ASSEMBLIES, NOSE WHEEL WELL, MAIN WHEEL WELLS
   - PROPULSION PODS – INLET ENGINE EXHAUST
3. VISUAL EXTERIOR CHECK
   - FUSELAGE – EXTERIOR SURFACE, WINDSHIELD AND WINDOWS, DOORS, RADOME, TAIL CONE
   - WINGS – UPPER AND LOWER SURFACES, WING TIPS CONTROL SURFACES
   - STABILIZERS – HORIZONTAL STABILIZER UPPER AND LOWER SURFACES, VERTICAL STABILIZER SURFACES, CONTROL SURFACES
4. OPERATIONAL CHECKS
   - COMMUNICATION AND NAVIGATION SYSTEMS
   - STANDBY AND ALTERNATE SYSTEMS
5. EQUIPMENT CHECK
6. SERVICING
   - LUBRICATION – LANDING GEAR ASSEMBLIES, CONTROL SURFACES
   - FILTERS – HYDRAULIC, FUEL
   - CHECK AND REPLENISH – AIR, LIQUIDS
7. SYSTEM COMPONENT CHANGES AT A PERIODIC CHECK
8. POSTSERVICE CLOSE UP

UNSCHEDULED WORK

1. PILOT'S REPORTS
2. INSPECTOR WRITE UPS

Figure 3–46. Line Maintenance Periodic Check

V4-B2707-1

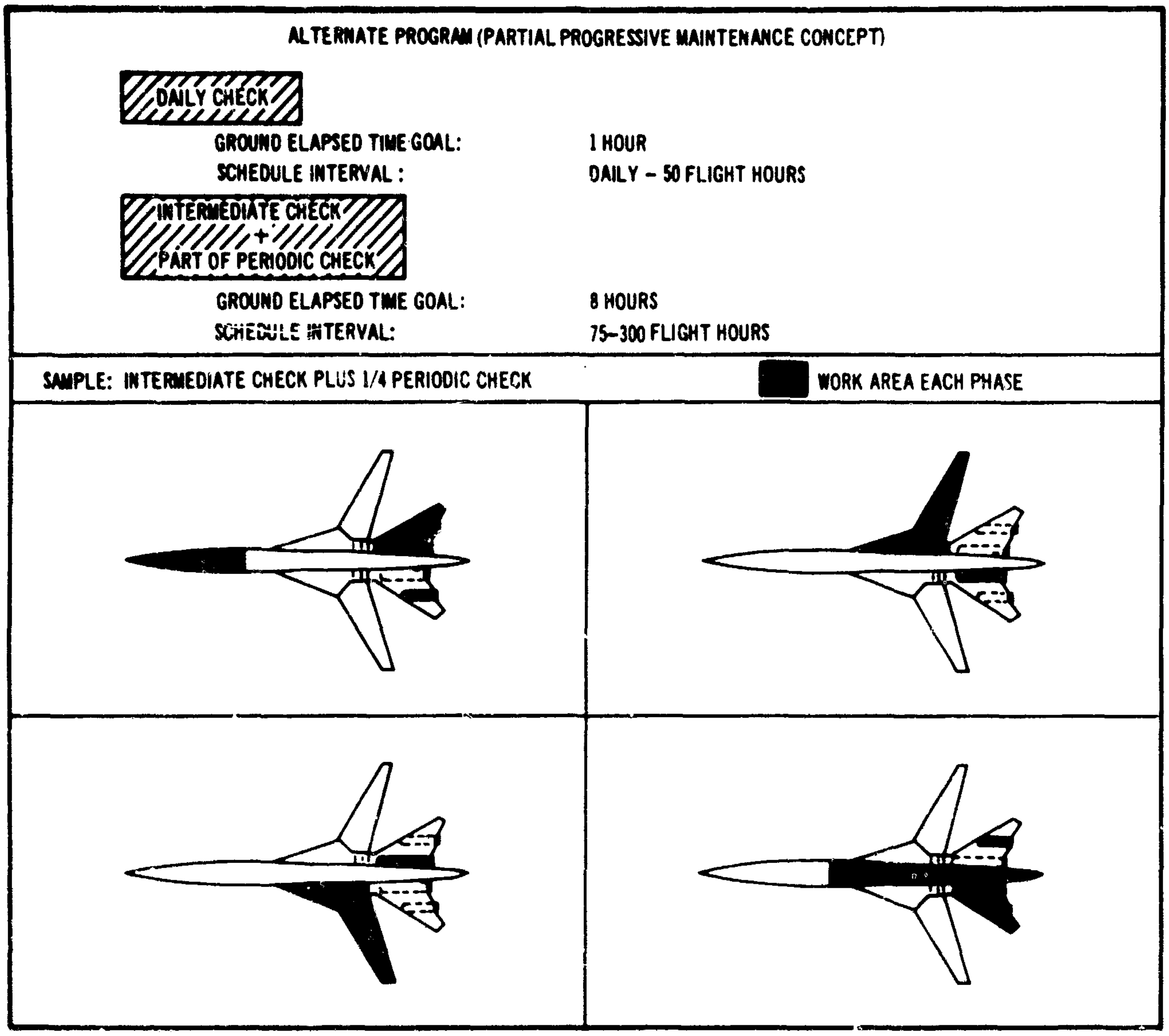


Figure 3–47. Line Maintenance – Alternate Program

tasks are to open up the airplane for a detailed structural inspection and, if required, repair. Refurbishing of the interior, detail inspection and functional check of systems, and component replacements are performed at the same time for convenience.

Inspection is conducted to verify structural integrity. The company has gained considerable experience in structural inspection techniques from the 707/720/727 programs. These techniques will be updated to coincide with developments in airline maintenance practices for the 737 and 747 programs.

The same techniques can be applied to the B-2707 to reduce manhours, elapsed time, and maintenance cost, as shown below:

- Sampling on different airplanes - Shorten airplane downtime by reducing number of inspections on each airplane.
- Nondestructive methods - Reduce manhours and elapsed time of inspections with techniques such as X-ray and eddy current.
- Rapid inspection interval escalation - Reduce manhours per flight hour, and thus total maintenance cost.

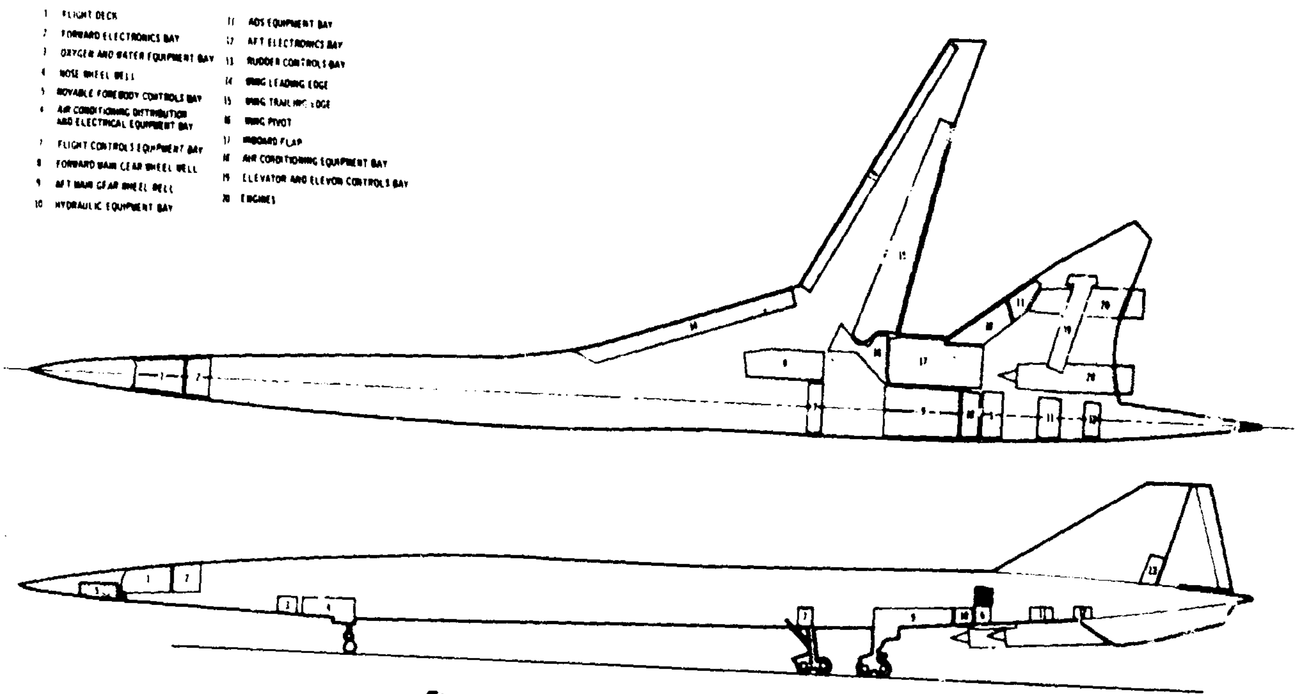


Figure 3-48. B-2707 Major Work Zones

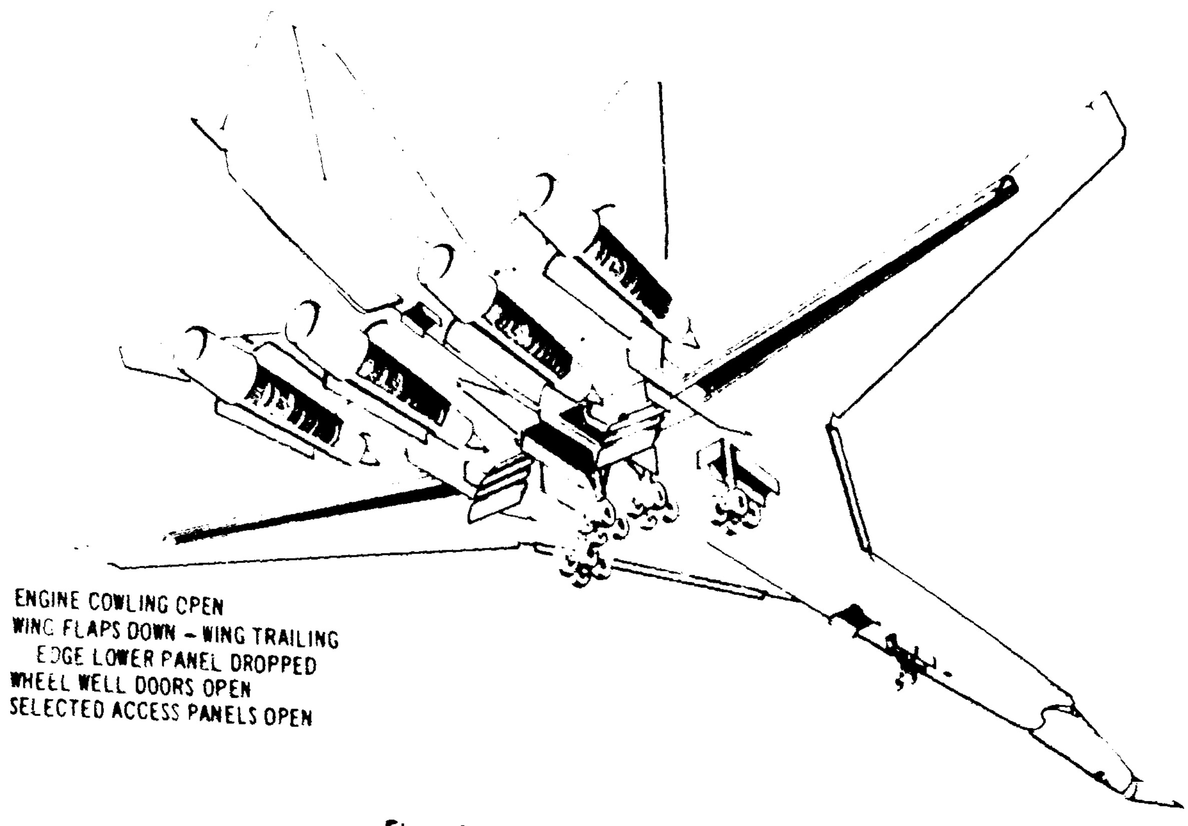


Figure 3-49. B-2707 In Periodic Check

- Quick-opening panels with latches are available at each accessory drive gear box compartment and the air-conditioning equipment bays.
- Landing gear wheel well doors are opened by operating a control handle at each wheel well.
- Two cowl panels with quick-opening latches are installed on each engine. Each panel is hinged and provided with a hold-open device.
- The bypass doors on the engine inlet are large enough for a mechanic to check the compressor blades for foreign object damage.
- With the wing flaps and slats down, all equipment installed on the front and rear spars is exposed.
- Hinged access panels with quick-opening latches are provided for servicing engine oil and lavatories. These panels provide sufficient access for a mechanic to work through with gloved hands.
- An access panel on the underside of each wing allows a quick check of the wing pivot cavity.
- Access panels are provided for all control surfaces.

The scheduled work requirements of the B-2707 are similar to current and planned subsonic jets. Accessibility and dispersed work zones have been incorporated into the design to enable the airlines to meet operational schedule commitments. Examination of the work content details will show that maintenance crews can adapt, with a minimum of training, to the requirements of the B-2707.

Ground support equipment for line maintenance is identified in GSE Requirements Specification, D6A10180-1. Training of maintenance personnel is discussed in the Training and Training Equipment Program, V4-B2707-7.

b. Unscheduled Maintenance. Accomplishment of unscheduled maintenance often causes airplane delay or out-of-service. In recognition of this situation, the B-2707 is designed with special features to facilitate:

- Rapid troubleshooting of systems
- Rapid replacement of components
- Conventional repair of minor structural damage

(1) Troubleshooting. The overall concept to improve the troubleshooting capability of the B-2707 systems is to provide adequate on-board facilities or instrumentation. The priority of troubleshooting methods is:

- Use airplane instrumentation
- Use airplane self-test features
- Use aircraft integrated data system (AIDS-optional equipment)
- Use ground test connections and ground support equipment

The basic airplane instrumentation has been expanded to include annunciator panels, which provide system trouble identification capability under dynamic flight conditions. This intelligence transmitted to the maintenance crew through pilots' reports, shortens the trouble analysis and rectification cycle.

Electrical/electronic equipment and systems incorporate maintenance self-test, permitting fault isolation to the component level. The self-test systems used are both the continuous monitoring type and mechanic-initiated type. The interface box concept of wiring installation provides a centralized termination of wires for troubleshooting of each individual system. In addition to flight deck instrumentation, the fluid and pneumatic systems incorporate test ports on components and in the systems to facilitate troubleshooting and condition determination. Those systems where transient conditions exist or the flight conditions cannot be duplicated on the ground are being considered for application of AIDS to provide readout on the ground as a supplement to basic troubleshooting provisions.

With the described provisions, flight line test ground support equipment (GSE) has been minimized. GSE is required for the following:

- To detect faults within the wiring and connectors between system components which cannot be detected by the self-test features
- To excite units which require excitation from sources external to the airplane
- To test airplane equipment for which self-test is not provided

(2) Component Replacement. During routine operation, structural and system components require replacement due to failure, malfunction, or damage. The capability to make replacements and then verify proper operation, all within the downtime of routine services and scheduled checks, is a design objective of the B-2707. Some examples of rapid replacement features being considered to meet this objective are given below:

- Major structural components, such as wing pivot bearing, control surfaces, landing gear assembly, and movable forebody, can be replaced within the 8-hour downtime limit.
- Any system component can be replaced without disturbing another installation.
- Dispatch-critical components can be replaced within the downtime of enroute or turnaround services.
- Quick-attach mountings are provided for components on the accessory drive gear box.

Although the B-2707 requires basically the same type of handling GSE as current jet transports, special techniques will be necessary to handle many components due to their increased sizes and weights, and heights above the ground.

A "bootstrap" method is used for engine change. Beams and slings are attached to hard points in the under surface of the horizontal stabilizer, permitting raising and lowering of the entire propulsion pod (engine with inlet and exhaust) or the engine section, inlet and thrust reverser-nozzle individually.

Jacking of the airplane for operations such as landing-gear cycling or gear change requires three hydraulic tripod jacks of conventional design. Commercially available axle jacks are used for wheel and tire change. Landing gear handling dollies, and wheel change dolly are designed for convenient and rapid accomplishment of the replacement operation.

Conventional wire rope and beam-type slings are used for overhead handling of control surfaces, removable body sections, and other components where size and weight preclude "man-handling." Where heavy components require removal and installation from beneath, an adjustable stand with adjustable features is provided.

(3) Minor Structural Repair. Minor structural repairs on the B-2707 will be similar to those made on current subsonic jets, even though the basic material has been changed from aluminum to titanium.

When a skin panel or a stringer is damaged, additional material can be spliced into the original material to enable the structure to carry the design loads. Minor repairs to titanium/fiberglass honeycomb will be similar to honeycomb repair on subsonic jets. Typical minor repairs are described in Airframe Design Report, Part B, V2-B2707-6-2.

Some transitional training of maintenance personnel in the techniques of troubleshooting, component replacement, and minor structural repair will be necessary (Ref. Training and Training Equipment Program, V4-B2707-7). This is similar to the current airline practice when new equipment is added to the fleet.

3.7.3.2 Base Maintenance

The work content of a basic check or airframe overhaul is illustrated in Fig. 3-50. The primary tasks are to open up the airplane for a detailed structural inspection and, if required, repair. Refurbishing of the interior, detail inspection and functional check of systems, and component replacements are performed at the same time for convenience.

Inspection is conducted to verify structural integrity. The Company has gained considerable experience in structural inspection techniques from the 707/720/727 programs. These techniques will be updated to coincide with developments in airline maintenance practices for the 737 and 747 programs.

The same techniques can be applied to the B-2707 to reduce manhours, elapsed time, and maintenance cost, as shown below:

- o Sampling on different airplanes - Shorten airplane downtime by reducing number of inspections on each airplane.
- o Nondestructive methods - Reduce manhours and elapsed time of inspections with techniques such as X-ray, eddy current.
- o Rapid inspection interval escalation - Reduce manhours per flight hour, and thus total main-

STANDARD PROGRAM (BLOCK MAINTENANCE CONCEPT)

BASIC CHECK	GROUND ELAPSED TIME GOAL:	120 HOURS
	SCHEDULE INTERVAL:	3,000 – 8,400 FLIGHT HOURS

SCHEDULED WORK – MAJOR TASKS

1. PRESERVICE OPEN UP
2. STRUCTURAL INSPECTIONS (STRUCTURAL INSPECTION PROGRAM)
   - FLIGHT CONTROLS – SPOILERS; LEADING EDGE SLATS AND TRAILING EDGE FLAPS-TRACKS, CARRIAGES, AND SUPPORTS; AILERONS; ELEVATORS AUXILIARY ELEVATORS AND ELEVONS; RUDDER
   - LANDING GEARS – NOSE GEAR AND MAIN GEAR – STRUT, AXLE, TRUNNION, TRUCK, TORSION LINKS, LOCKS
   - DOORS – PASSENGER, CARGO, GALLEY, SERVICE
   - FUSELAGE – SKIN PANELS, PRODUCTION JOINTS, PRESSURE BULKHEADS, BODY FRAMES, SKIN AND FRAME AROUND DOORS, EXITS, AND WINDOWS, ATTACHING FITTINGS TO NOSE GEAR, WING AND STABILIZERS, FLOOR BEAMS, VENTRAL FIN, MOVABLE FOREBODY
   - NACELLES – ENGINE MOUNT FITTINGS
   - STABILIZERS – SPARS, INTERNAL STRUCTURE, ATTACH FITTINGS, SKIN PANELS
   - WINGS – CENTER SECTION AND OUTBOARD WINGS – WING PIVOT, SKIN PANELS, FRONT AND REAR SPARS, INTERNAL STRUCTURE, ATTACHING FITTINGS TO MAIN GEARS, CUTOUTS
3. AREA INSPECTIONS AND REFURBISHING
   - FLIGHT DECK
   - PASSENGER CABIN
   - CARGO COMPARTMENTS
   - GALLEYS
   - TOILETS
4. SYSTEM COMPONENT CHANGES (COMPONENT OVERHAUL PROGRAM)
5. DETAIL INSPECTION – ALL SYSTEMS
6. FUNCTIONAL CHECK – ALL SYSTEMS
7. EQUIPMENT CHECK
8. SERVICING
   - LUBRICATION
   - FILTERS
   - AIR, FLUIDS
9. POST SERVICE CLOSE UP

UNSCHEDULED WORK
INSPECTOR WRITE-UPS

MODIFICATIONS

ALTERNATE PROGRAM (PROGRESSIVE MAINTENANCE CONCEPT)
DIVIDE BASIC CHECK WORK CONTENTS INTO SMALL PACKAGES AND SCHEDULE WITH LINE MAINTENANCE PROGRAM.

Figure 3-50. Base Maintenance – Basic Check

tenance cost.

Excellent access has been provided to the interior of closed structural compartments, such as fuselage fuel tanks, wing center section, and outboard wing. The requirement for crawling inside the compartment has been reduced to a minimum. Engineering, quality control, and manufacturing departments are conducting many tests to develop titanium and sandwich panel inspection and repair methods, which can be used by airlines in the field. Airframe Design Report, Part B, V2-B2707-6-2 describes access provisions to structural compartments, structural inspection methods, and typical repair methods for the various sections of the B-2707.

The basic concept of the B-2707 component overhaul program is to provide adequate capability for condition determination. This resulted from a review of the many programs established by the airlines for current jets under FAA advisory Circular 120-17 and Boeing's conclusion that the same technique can be applied to all systems of the B-2707. Thus, adequate test points are incorporated in the basic system and component designs to allow testing and condition determination of components without removal from the airplane. Most components will be in an "on condition" status and systems or individual components will be functionally tested at the basic check. The advantages of this are:

- Maximum use of component life to reduce component overhaul cost
- Elimination of unnecessary disturbance to installations to reduce delays and discrepancies
- Prevention of infant mortalities after overhaul to reduce unscheduled removals

The provisions on the B-2707 for "on condition" component replacement are described in Systems Reports, V2-B2707-10 and V2-B2707-11, and Propulsion Reports, V2-B2707-12 and V2-B2707-13.

Interior linings of commercial jets are installed in individual panels, rather than in continuous sheets as is done in propeller-driven airplanes. The need to refurbish the entire passenger cabin in one operation during the downtime of a basic check has disappeared. Refurbishing can now be performed in sections and accomplished during the line maintenance program. The use of new materials on the B-2707 that do not soil or damage easily is expected to increase the intervals between refurbishings.

Current airline practice will be applied for overhaul of airborne accessories. Although sizes and weights are greater than existing equipment, the principles of design, construction, and operation follow conventional trends. Wear and rework tolerances, assembly and disassembly procedures, and test procedures will be supplied by the equipment manufacturers in detail. Complete and up-to-date overhaul data are assured by enforcement of the product support agreement described in the Product Support Program, V4-B2707-20.

Emphasis has been placed on the use of the modules within an assembly. Subassemblies (modules) may be overhauled at different intervals and checked out without checking out the complete assembly. Further, prior to final assembly of a complete unit, subassemblies will be tested to reduce time in the final assembly phase. This method provides substantial improvement in reliability and economy.

Engine overhaul is discussed in the engine manufacturer's proposal. It is expected that supersonic engines will easily be integrated into subsonic engine overhaul shops.

Test GSE is required to complete engine and accessories overhaul. Definition of these requirements will be made during prototype development. Some of the major items defined at this time are an engine test stand, an engine inlet test unit, a hydraulic test bench and an inertial navigation system test set. These are described in GSE requirements Specification, D6A10180-1.

Overhaul of the airframe, engine, and airborne accessories does not require extraordinary skills and training. Maintenance personnel handling overhauls today are capable of increasing their proficiency to the required level.

3.7.4 Spares

The spares program, outlined in the Product Support Program, V4-B2707-20, is designed to satisfy the unique operational support requirements of each individual customer airline. The Spare Parts Requirements Forecasting Computer Program (Product Support Program, V4-B2707-20) is responsive to airline operational peculiarities and will consider route structure, flying-hour program, line-station requirements, minimum downtime, dispatch reliability, and overhaul schedules in developing spare parts recommendations. The spare part inventories at both Boeing and vendor facilities, will provide the necessary parts to rapidly compensate for airline changes in route structure or utilization. Boeing personnel will be available at all times to coordinate unforeseen problems or emergencies, such as an AOG.

CONTENTS

4.0 AIRPORT SUITABILITY REPORT

The development of an American supersonic transport is an announced national goal, towards which progress is being accomplished on schedule. The SST that will be offered to the airlines of the world will be safe, economical, capable of a cruising speed at least three times greater than today's aircraft, and compatible with the airports it will serve and with the neighboring communities.

One of the requirements of the FAA contracts has been the submission of reports on the operational compatibility of the proposed design with the following U.S. international airports:

- ANCHORAGE INTERNATIONAL (ANC)
- FRIENDSHIP INTERNATIONAL (BAL)
- LOGAN INTERNATIONAL (BOS)
- O'HARE INTERNATIONAL (ORD)
- DETROIT METROPOLITAN WAYNE COUNTY (DTW)
- HONOLULU INTERNATIONAL (HNL)
- HOUSTON INTERCONTINENTAL (HOU)
- LOS ANGELES INTERNATIONAL (LAX)
- MIAMI INTERNATIONAL (MIA)
- JOHN F. KENNEDY INTERNATIONAL (JFK)
- PHILADELPHIA INTERNATIONAL (PHL)
- PORTLAND INTERNATIONAL (PDX)
- SAN FRANCISCO INTERNATIONAL (SFO)
- SEATTLE-TACOMA INTERNATIONAL (SEA)
- DULLES INTERNATIONAL (DIA)

As part of the work accomplished during Phase II-A of the supersonic transport program (Contract No. FA-SS-64-4), The Boeing Company, in 1964, investigated the compatibility of the then current design with the 15 airports listed previously. An individual report on this analysis was released on October 22, 1964; a summary report (Vol. XVII-A) was delivered to the FAA on November 1, 1964, as part of the Comprehensive Report on Phase II-A.

During the week of October 4, 1965, it was agreed among representatives of the Airport Operators' Council, the Supersonic Transport Development Office of the Federal Aviation Agency, and the two competing airframe contractors that each contractor should, as part of his SST development contract, evaluate specific airport compatibility characteristics of its own SST design and estimate the costs of those modifications to airport facilities that would be required to produce compatibility. Due recognition would be given to certain airport improvements that will be required for interim subsonic aircraft.

To perform the major share of the required airport compatibility evaluations and cost estimations during Phase II-C, the company twice retained the firm of Howard, Needles, Tammen, and Bergendoff, Consulting Engineers. The first engagement occupied the period October 19 - December 22, 1965, and resulted in the Phase II-C preliminary report, which was coordinated with the airport operators, and submitted to the FAA on January 1, 1966. The second engagement occupied the period June 7 - August 22, 1966, and resulted in the Phase II-C Final Report. This report was transmitted to the operators and submitted to the FAA, concurrently with the Phase III proposal, on September 6, 1966.

This section of V4-B2707-1 provides a summary of the results of B-2707 airport suitability evaluations performed during the Phase II-C supersonic transport program. The study was based on the B-2707 configuration data and requirements and airport data collected from individual airport operators through correspondence, interviews, and comments on preliminary evaluation reports. The airport suitability plan for Phase III is shown in Par. 5.5 of this document.

4.1 SUMMARY

The development of an American supersonic transport suitable for operations at the world's major international airports has been a major design objective. A continuing Airport Suitability Evaluation Program has been conducted to assure meeting this objective. The Suitability Program has consisted of detailed investigations conducted

on 16 representative U.S. international airports. These investigations encompassed the major aspects influencing compatibility between the airplane and the airports. Included in these investigations were the following specific areas:

- Pavement requirements
- Ground maneuvering
- Holding areas and aprons
- Underpavement structures
- Overpasses and bridges
- Passenger handling facilities
- Fueling facilities
- Engine blast protection
- Runway lengths
- Fire and rescue equipment
- Cost estimates

The 675,000 lb B-2707 was found to have pavement thickness requirements very little different from existing subsonic jet transports weighing approximately half the weight of the B-2707. This is primarily due to the fact that each of the B-2707's main landing gears applies essentially the same load to the pavement as each of the gears of the large conventional subsonic jet transports.

Within limits anticipated for routine operations, the B-2707 can be maneuvered smoothly around any runway-runway intersection and any runway-taxiway intersection paved with fillets of the radii recommended by the FAA. At certain taxiway-taxiway intersections, however, the fillet radii are inadequate. Of the total of 1,472 fillets and curved taxiways investigated, 323 required enlargement for normal maneuvering. These findings were based on a practical clearance between the centerline of the outside truck and the pavement edge while rolling the nose wheel in a direct, smooth path from pavement centerline to pavement centerline.

Holding aprons at the ends of runways are of less importance to jet-powered airplanes than to piston-engine airplanes which require engine runup. Holding aprons serve as an area in which airplanes lacking departure clearance or requiring last-minute functional checking can wait while those behind can pass. Instances of one SST having to pass another on a holding apron will probably be rare; however, passing of contemporary subsonic jets presents as great a clearance problem. To accomplish this maneuver, a few holding aprons among those investigated require some increment of widening. This requirement was not a significant contributor to the overall cost anticipated for facilities improvement at the airport.

The dimensions of the B-2707 imposed a similar problem at the terminal aprons for certain airports. At those airports where the length and span influence the ability of other airplanes to pass, enlargement of terminal aprons will be required.

At every airport investigated, pavements subjected t airplane loading were found to be underlaid by structures such as pipes, culverts, and utility conduits. The worst case determined indicated the B-2707 would impose approximately 8 percent greater stress on some structures than current subsonic transports. These substructures show no evidence of distress from loads imposed by current subsonic airplanes. Removal or replacement of undamaged structures for an anticipated increase in loading of only 8 percent would serve little purpose. As a result, the B-2707 is considered compatible with these items.

At 5 of the 15 airports investigated, there are, or soon will be, overpass structures or vehicular subways carrying airplane live loads. Serious overstressing would be occasioned by the B-2707 on some existing structures; however, equally serious overstressing would occur if these structures were subjected to loading by some current and forthcoming subsonic transports. It is anticipated that these structures will have been improved prior to introduction of the B-2707 into service. For this reason, the B-2707 is considered compatible.

The principal impact of the B-2707 on the terminal gate facilities involve alterations to passenger loaders. The forward door of the B-2707 is compatible with the existing telescoping swing-type loaders. The location of the other passenger loading doors will require modifications to second-story passenger loaders. The study shows that a minimum of 159 loading positions will accommodate the B-2707 at the 14 airports using at-terminal passenger loading practices.

At those airports where underground fuel distribution systems are not installed or planned, it will be practical to refuel the B-2707 from large tank

trucks. Most existing underground systems have combined fueling rate capacities at the planned gate loading positions in excess of the B-2707 requirements. The only anticipated improvement would be changing the 2-1/2 in. hydrants and laterals to 4 in. and locating them for accessibility to the supersonic transport.

Engine exhaust velocities for the B-2707 are higher than for present subsonic jets. However, the greater height of the B-2707 engines as compared to those of current underwing engines tend to offset the effects of higher velocities as related to personnel and vehicles on the ground. As a result, the B-2707 is considered suitable for ground operations without airport modifications.

The B-2707 provides a combination of high thrust engines and the variable-sweep wings which result in runway length requirements compatible with those of conventional subsonic jet transports.

The advent of subsonic jets with passenger carrying capacity comparable to the B-2707 is not expected to necessitate the development of new types of rescue equipment. Valuable extra minutes of protection for the occupants of the B-2707 may be gained from the temperature resistant titanium fuselage. Fire and rescue equipment beyond that in service when the B-2707 is introduced into service is not anticipated.

At the 15 airports studies, the total cost of modifications is $5,528,000. This figure does not include costs of improvements and airport expansions which will have been occasioned by introduction of the stretched version and large capacity subsonic transports into service prior to the B-2707. Where the situation warrants, both a best and high estimate have been included. These costs do not include the cost of modifying fuel systems or passenger loaders. Modifying fuel systems and passenger loaders is dependent upon the number of gate positions actually utilized by the B-2707. Average costs per gate position at a given airport for modification of passenger loaders varied from $40,000 to a high of $150,000. Similarly, the average cost for fuel systems varied from $7,000 to $22,000 per gate position. The airport modification cost summary for the 15 study airports is shown on Table 4-A.

The present design of the B-2707 has essentially met airport suitability objectives. The overall compatibility of the B-2707 with current and planned airports is excellent. Recognition of continuing improvements and expansion programs at the world's airports to keep pace with air traffic growth should provide an airport network into which the B-2707 can be introduced without significant need for major investments.

4.2 ASSUMPTIONS AND CRITERIA FOR EVALUATIONS

4.2.1 Items Evaluated

The suitability characteristics which have been evaluated include the following specific items:

- Pavement strength or thickness
- Pavement geometry -- fillet radii, holding aprons, terminal aprons, terminal area inlays
- Evaluation of structures -- overpasses and bridges, underground pipe and conduits
- Terminal area considerations -- maneuvering and docking, passenger handling, fueling
- Blast effects -- ground operations, runway erosion
- Runway length
- Fire and rescue equipment

4.2.2 Characteristics of the B-2707

The B-2707 employs the principle of variable-wing geometry. During takeoffs, landings, and normal ground operations, the B-2707 operates with its wings in the full-forward position. In this position, the leading edge of the wings have a sweep of 30 degrees from a line perpendicular to the centerline of the fuselage. For supersonic cruise, the wings are swept to a position of 72 degrees so that their trailing edges fair into the leading edges of the horizontal tail surfaces. The principal dimensions and clearances of the B-2707 are as given in Fig. 4-1.

The B-2707 has been designed so that its nose can be articulated downward for purposes of optimizing the pilot's vision during subsonic operation, including takeoff, approach, landing and taxiing.

The main landing gear comprises two pairs of dual-tandem trucks. The aft pair of trucks is spaced inboard of the forward pair, and are coupled to steer with the nose gear.

Table 4-A. Airport Modification Cost Summary

Average Per Gate Costs				Cost of Other Modifications	
Apron Inlays	Fuel System Modifications	Passenger Loader	Airport	Best	High
-	20,000	-	Anchorage	88,000	-
18,000	-	-	Friendship	19,000	-
-	-	-	Logan	127,000	-
-	12,000	50,000	O'Hare	88,000	-
-	8,000	50,000	Detroit	127,000	-
-	17,000	-	Honolulu	324,000	-
-	7,000	-	Houston	246,000	-
-	20,000	80,000	Los Angeles	1,336,000	1,486,000
-	7,000	100,000	Miami	100,000	-
-	20,000	67,000	John F. Kennedy	2,490,000	4,190,000
-	-	-	Philadelphia	166,000	-
-	-	40,000	Portland	24,000	-
30,000	22,000	68,000	San Francisco	120,000	660,000
-	11,000	150,000	Seattle-Tacoma	43,000	-
-	16,000	-	Dulles	230,000	-
			Totals	5,528,000	7,918,000

4.2.2.1 Gross Airplane Weights
The maximum gross ramp weight of the B-2707 is 675,000 lb. The maximum gross takeoff weight is 672,000 lb. For purposes of the studies reported in this document, 97 percent of the airplane weight is assumed to be distributed equally to the four trucks of the main landing gear.

4.2.2.2 Main Landing Gear
Pertinent data on main landing gear assemblies of the DC-8-55 and B-2707 are in Figs. 4-1 and 4-2.

4.2.2.3 Fueling
Fueling is accomplished through four ports located in the underside of the wings, about 178.5 ft aft of the nose and about 21 ft outboard of the fuselage centerline. The ports are about 12 ft above the ground. Delivery rate is to be 2,000 gpm, at a maximum pressure of 50 psi. The total usable capacity is 54, 790 gal. The fuel is the same as used by subsonic jets.

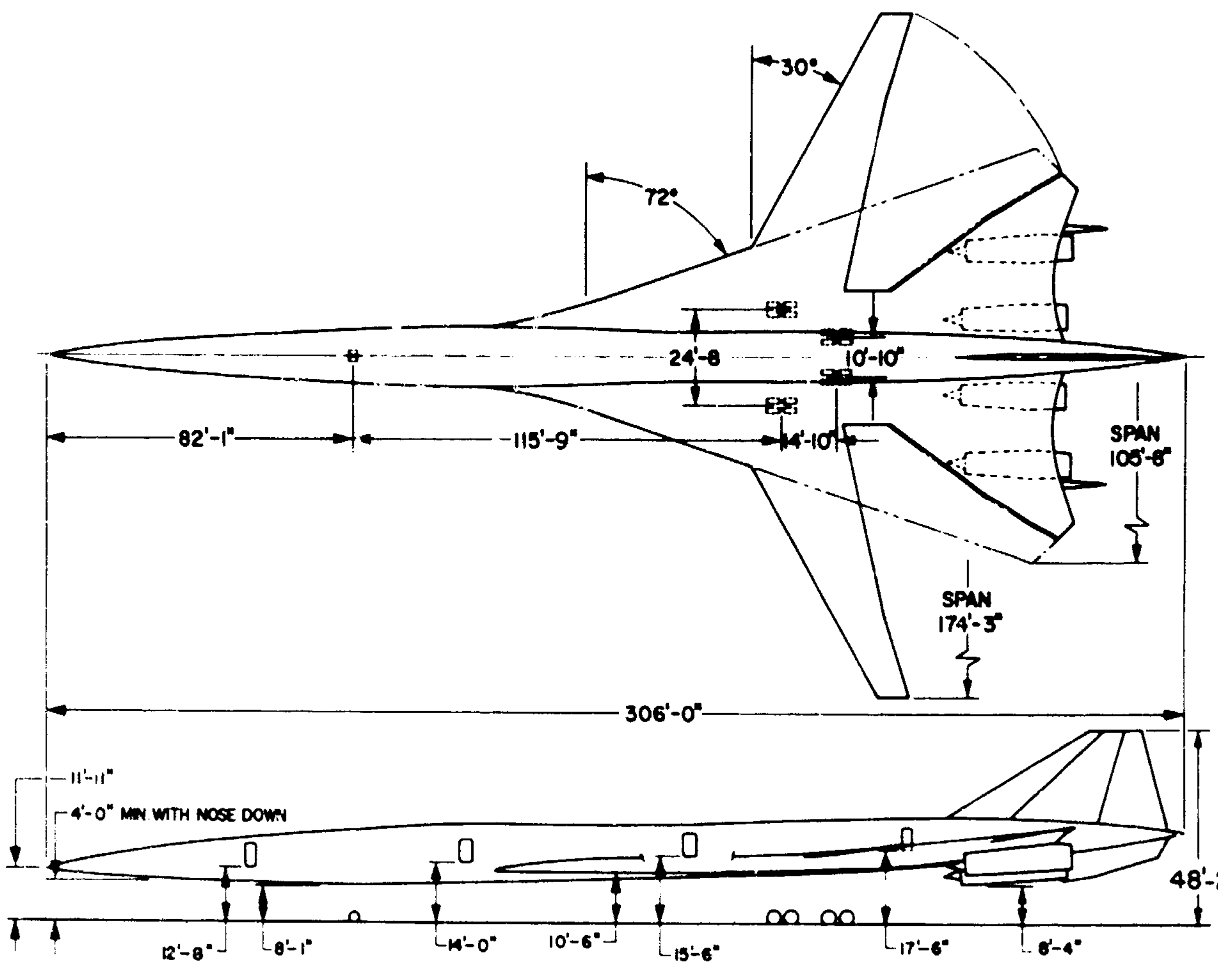


Figure 4-1. B-2707 Principal Dimensions

4.2.2.4 Ground Maneuvering
Figure 4-3 is a composite of ground maneuver landing gear tracks at typical runway-taxiway and taxiway-taxiway intersections. Figure 4-4 is a tabulation of turning radii for various nose gear steering angles.

4.2.3 Evaluation Criteria and General Results

4.2.3.1 Pavement Thickness
The B-2707 pavement requirements analysis for the 15 designated airports is of sufficient scope and importance that it has been treated as a special item. The detail analysis which forms the basis of this report is included in Airport Pavement Requirements for the Boeing Supersonic Transport, Model 2707, D6A10317-1 (Ref. 14). Included is a full discussion of the assumptions and analytical methods employed, as well as a tabulation of the calculated induced stresses or pavement thicknesses required for all known pavement and subgrade combinations at each study airport. The three pavement design charts shown on Fig. 4-5 show the relative requirements for the DC-8-55 and B-2707. The subgrade characteristics included in this report have been obtained from the respective airports. Discussions held with the engineers at most of the study airports have yielded additional information on the behavior of subgrades supporting airfield pavements. The most recent investigation included visual observations of pavement conditions at a number of the study airports by members of Howard, Needles, Tammen, and Bergendoff.

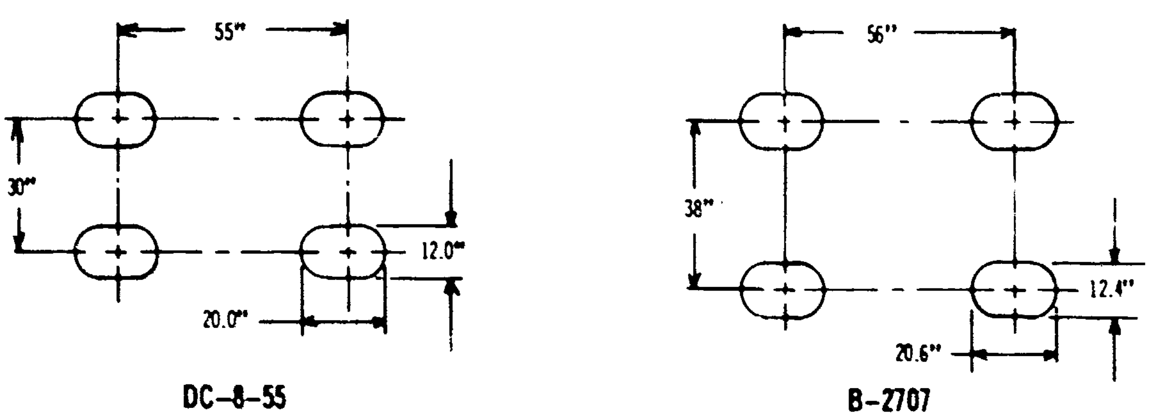
Figure 4-2 shows the configurations of the four-wheel, main-gear trucks of the DC-8 and the B-2707. Also shown are such pertinent data as tire sizes, inflation pressures, and assumed tire contact area.

It has been agreed among the Airport Operators' Council, the Supersonic Transport Development Office of the FAA, and the two airframe contractors engaged in the supersonic transport program that the DC-8-55, having a maximum gross ramp weight of 328,000 lb is an acceptable comparison vehicle for pavement compatibility evaluations. While this criterion has been strictly observed in the present study, recognition has also been given to the fact that at almost every airport there are pavements rarely or infrequently used by airplanes operating at maximum ramp or takeoff weights. High-speed exit taxiways, taxiways leading to maintenance and overhaul areas, and the aprons located there are examples. Since the maximum landing weight of the B-2707 is only 60 percent of its maximum ramp weight, an effort has been made to identify all such pavements at each of the airports studied. They have been shown on certain airport photographs with the legend: "Little or no use by fully loaded SST anticipated."

At those airports which use the FAA method of flexible pavement analysis, the DC-8-55 requires a greater pavement thickness for all values of subgrade strength classification. As a result, no new overlays on flexible pavements have been assessed against the B-2707 where FAA procedure is the exclusive method employed by the airport operator.

At airports which provide subgrade classifications for the Corps of Engineers' method, with or without other means of flexible pavement analysis, rationalization and engineering judgment was necessary to establish the overlay requirement attributable to the B-2707. The rationale used in each case is included in the text of the specific airport.

At most locations where rigid pavement is used, the combinations of pavement thicknesses and subgrade strength result in lower flexural stresses for the B-2707 than the DC-8-55. In the few instances where the reverse is true, the pavements are overstressed by both airplanes and only very slightly more for the B-2707. Owing to the differences in their flotation characteristics, however, the gear of the DC-8-55 generally requires a slightly thicker flexible or bituminous corrective overlay. Consequently, no costs for overlays on rigid pavement have been assessed against the B-2707.



	DC-8-55	B-2707
Maximum gross weight	328,000 lb	675,000 lb
Tire size	44 in by 16 in	45 in by 19.2 in
Tire inflation pressure	187 psi	185 psi
Per cent MGW on nose gear	5.0	3.0

Figure 4-2. Main Landing -- Gear Truck Data

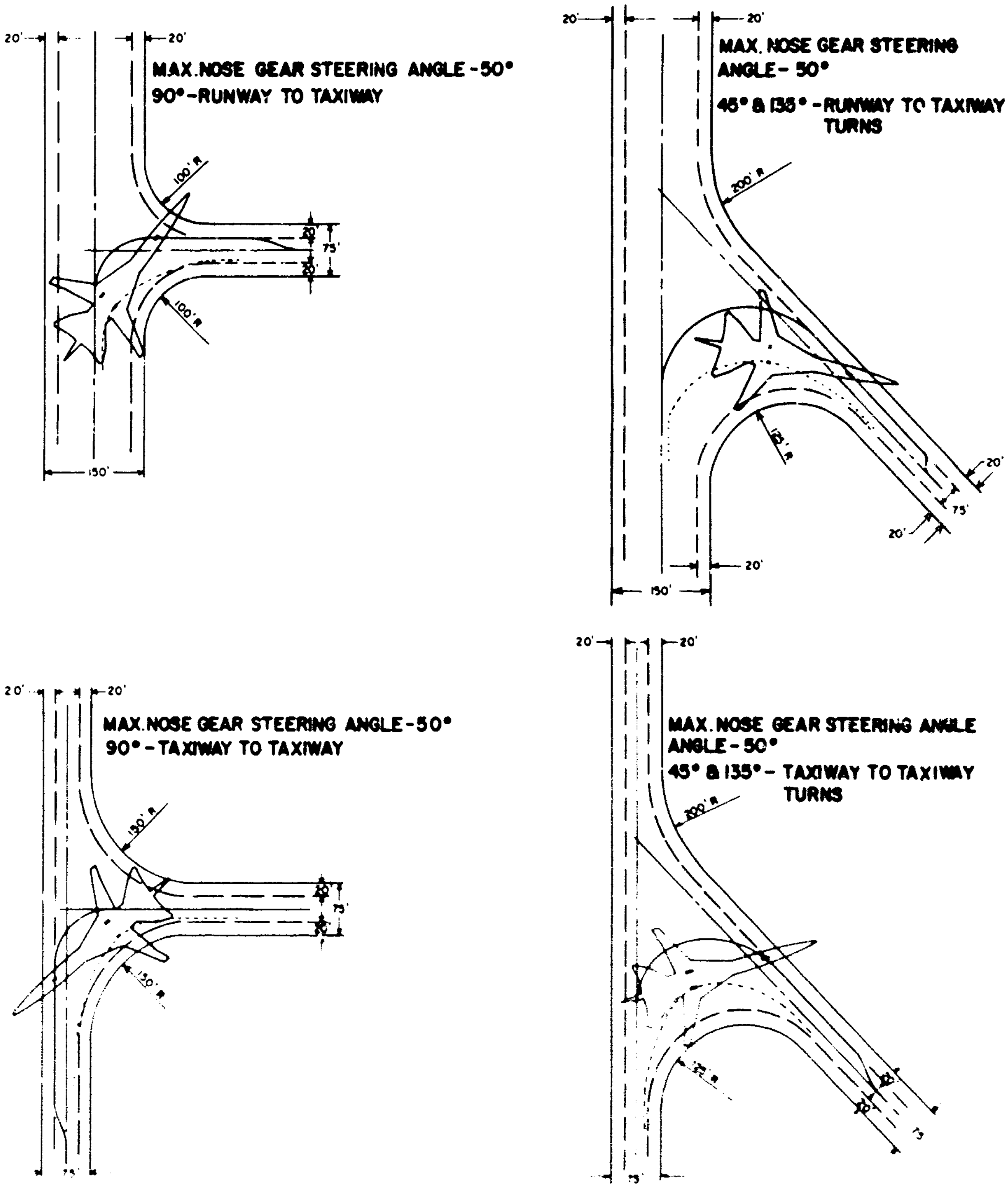


Figure 4-3. Minimum Fillet Requirements

Steering Angle (Degrees)	R1 (Feet)	R2 (Feet)	R3 (Feet)	R4 (Feet)	R5 (Feet)
45	103	128	163	194	227
50	84	109	151	184	218
55	68	93	141	171	213
60	54	79	133	157	208
65	41	66	127	145	205
70	29	54	123	134	202
76 Maximum	16	41	119	121	199

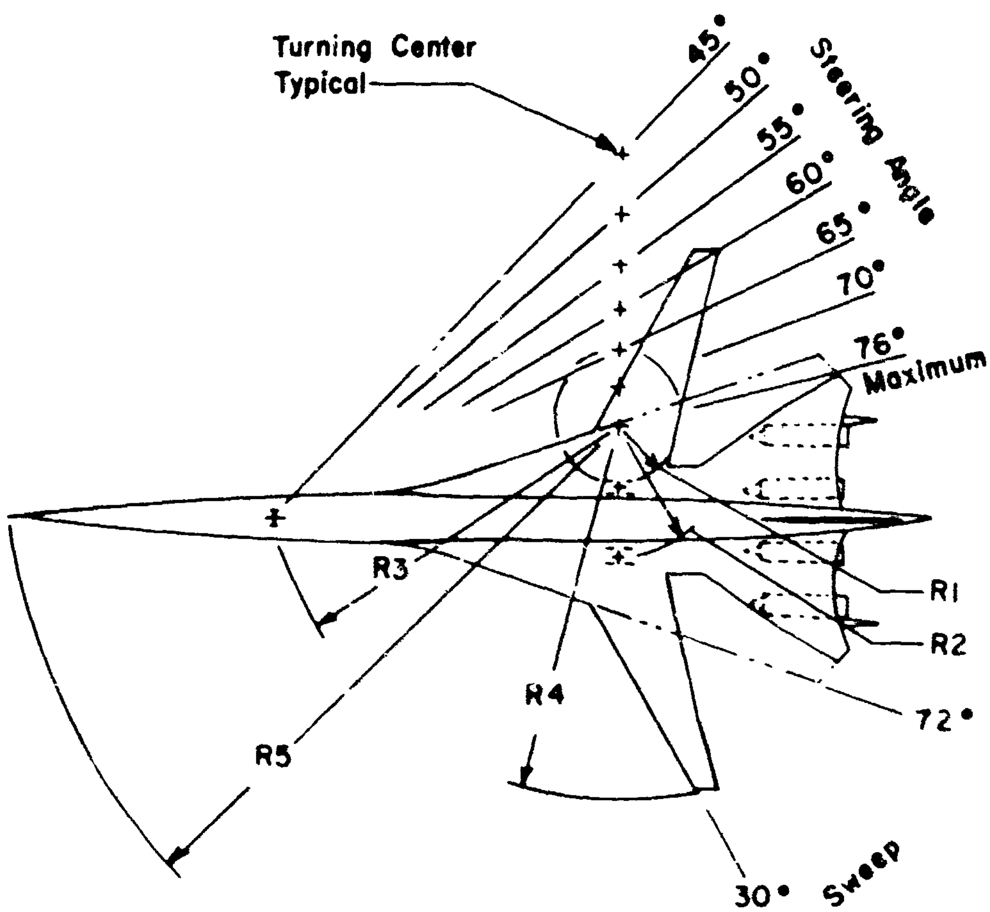
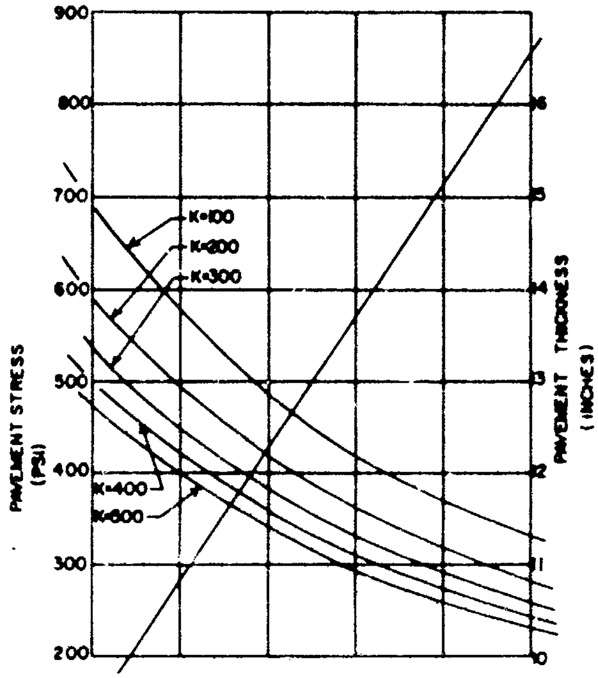
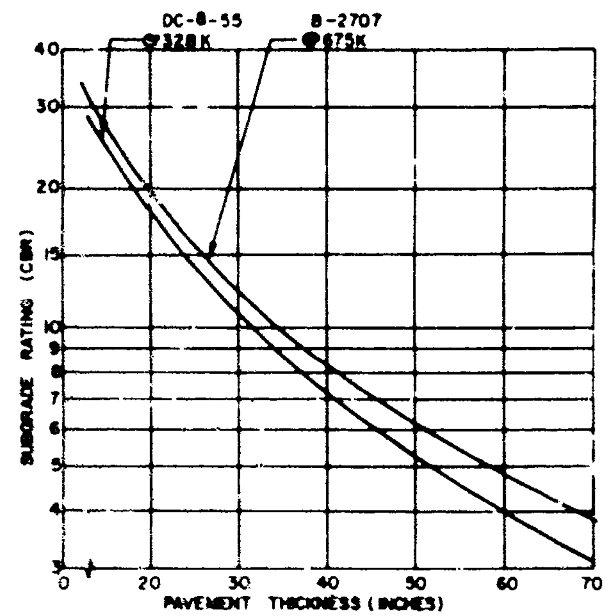


Figure 4-4. Turning Radii

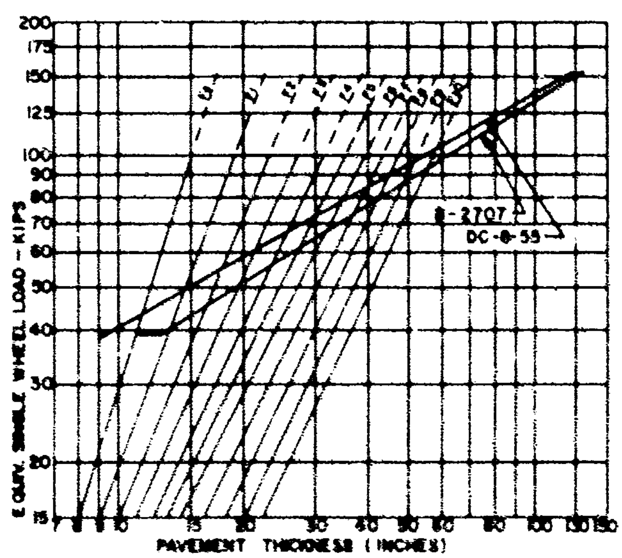
V4-B2707-1



STRESS IN RIGID PAVEMENT
675^k B-2707



FLEXIBLE PAVEMENT REQ'MTS
CORPS OF ENGR'S METHOD
DC-8 VS B-2707



FLEXIBLE PAVEMENT REQUIREMENTS
F.A.A. METHOD

Figure 4-5. Pavement Design Charts

4.2.3.2 Pavement Geometry

Figure 4-1 shows features and dimensions of the B-2707 that are pertinent to the present investigation. The size of the airplane and its turning characteristics will require that certain modifications be made to some existing taxiway fillets and end-of-runway holding aprons.

Fillets at pavement intersections were evaluated by model studies performed with the gear assembly configuration of the B-2707 reduced to a scale of 1 in. equals 10 ft. Rolling turns were used to obtain the best possible approximation of actual operating conditions.

Studies made in this manner indicate that the critical requirement for the smooth negotiation of intersection turns is st ting them at the right point. In recognition this finding, the criteria adopted for normal operations of the B-2707 provide adequate margins for misjudgment by the pilot of the optimum turning point. These margins are achieved by using a 50-degree nose-wheel steering angle, rather than the maximum 76 degrees possible, and by limiting to 20 ft the minimum clearance from centerline of outside truck to edge of full-strength pavement. In addition, the maneuvers studied for normal operations were made by rolling the nose wheel in a direct, smooth path from the centerline of one pavement to the centerline of the other without weaving away from the centerline prior to actually starting the turn.

Within the limits adopted for routine operations, it way found that the B-2707 can be maneuvered smoothly around any runway-runway intersection and any runway-taxiway intersection paved with fillets of the radii recommended by the FAA in its Advisory Circular 150 5335-1 (Ref. 15). At certain taxiway-taxiway intersections, however, the fillet radii recommended by the FAA are inadequate, in terms of the adopted criteria, for B-2707 taxiing operations.

At most airports there are intersections which could require an awkward taxiing maneuver (e.g., turning the acute angle of a high-speed exit taxiway). Since these are not normal maneuvers, a less rigorous set of criteria has been used. The operating limits adopted for these rarely made intersection maneuvers permit the use of the maximum nose-wheel steering angle (76 degrees), weaving away from the direction of turn prior to starting it, and a reduction of 10 ft in the clearance between the edge of pavement and centerline of nose or main-gear truck. Minimum fillet radii for a wide range of turning angles were determined for various combinations of widths of intersecting paven. nt in accordance with each set of criteria.

The first step in the study of intersection fillets at the individual airports was the elimination of those fillets that the B-2707 would never use, such as entrances to cargo areas, etc. Next, each remaining fillet was classified either as rare or normal usage. In marginal cases, the fillets were conservatively classified as normal usage pavements.

Where applicable, the standards developed for the study were used to determine the adequacy of the existing or planned construction. A separate model study was performed for each intersection for which the study standards were found inapplicable.

Quantities were determined for the improvements required to bring each inadequate fillet up to the set of study standards by which it has been classified. Current unit prices for materials and labor were applied to the estimated quantities to determine the costs of improvements. All such costs have been allocated to the B-2707 and are reported in the summary of costs found at the end of the individual airport reports.

Holding aprons at the ends of runways are of less importance to jet-powered airplanes than to piston-engine airplanes, which require them for engine runup. Nevertheless, the holding apron will continue to serve as an area in which aircraft lacking departure clearance or requiring additional last-minute functional checking can wait while those behind them pass.

Instances of one B-2707 passing another on a holding apron will be rare. It has been assumed that the passing B-2707 would sweep its wings to gain clearance. The adoption of this assumption makes the combination of a B-2707 and a large, current subsonic jet on holding aprons critical. The combination selected for the study was a present day jet with a wing-span of 142 ft and the B-2707, which has a 174-ft wing-span. Depending upon the geometry of the apron, the B-2707 (assumed to be the holding airplane) was parked either parallel to the long edge of the apron or at a slight angle to it. In maneuvering into its parked positions, the criteria of 50-degree nose-wheel steering angle and 20-ft pavement edge distance were observed. The

subsonic jet was required to pass on the taxiway centerline while clearing the B-2707 by at least 25 ft. Where necessary, the modifications required by these criteria have been designed and all costs associated therewith have been estimated, including the resetting or addition of edge lights.

Terminal aprons and the layout of concourses at some airports are such that aircraft parked at the outermost gate positions are too close to the periphery of the apron to permit the passage of a B-2707. Although other large airplanes entering service prior to the B-2707 will probably necessitate increased apron widths in such terminal areas, the costs of appropriate modifications have been estimated and allocated to the B-2707.

Terminal area inlays have been provided at some of the study airports. These are concrete pads at the gate positions which prevent rutting (which frequently occurs when flexible pavements are subjected to static or highly channelized loads) and pavement deterioration caused by fuel spillage. At those airports where the management or tenant airlines have installed an appreciable amount of rigid-pavement inlay, it has been assumed that inlays would be required at the B-2707 gate positions. An inlay 75 ft by 130 ft would provide an ample margin around the fueling stations, main gear, and engines; inlays of this size have been assumed for estimating purposes.

4.2.3.3 Structures

At every airport investigated, it has been found that pavement subjected to airplane loadings is underlain by items such as pipes, culverts, utility conduits, and baggage channels. At five airports, there are, or soon will be, overpass structures or vehicular subways carrying airplane loads.

Static B-2707 loads and their arrangement are the same as those used for the evaluation of pavements. Impact loads have been neglected for all structures, except overpasses and culverts with less than 3 ft of cover. Individual considerations of their span lengths led to the adoption of rolling impact factors ranging from 10 to 30 percent of the static load. It was assumed that any structure requiring a strengthening modification will in actuality, be redesigned by the airport operator for a growth version of the critical airplane. Therefore, structures requiring modifications chargeable to the B-2707 at a gross weight of 675,000 lb were redesigned for an airplane distributing 745,000 lb in the same manner as the basic B-2707, for cost estimating purposes.

The properties of all structural materi[illegible] were assumed to be those required by the sp[illegible]ications to which they were constructed. Assum[illegible] soil bearing values were those used by the c[illegible]inal designers.

Overpass deck slabs, the top slabs of b[illegible]ulverts, and other underground structures havin[illegible]ss than 2 ft of full cover have been analyze[illegible]r a live-load distribution based on orthotr[illegible] plate theory; this accounts for the relative st[illegible]ss of the slab parallel and normal to the span [illegible]gth. The top slabs of box culverts and underg[illegible] structures having a fill cover of greate[illegible]n 2 ft have been analyzed for a live-load distri[illegible]ion in accordance with Item 1.3, "Distribution [illegible] wheel Loads Through Earth Fills," of the Stan[illegible] Specifications for Highway Bridges adopt[illegible] by the American Association of State Highway [illegible]ials, Eight Edition, 19[illegible] (Ref. 16). The botto[illegible] slabs of box culverts and the footings of underg[illegible]nd structures have been analyzed for a live-[illegible] distribution in accordance with the same ref[illegible] item, except that the loads have been dist[illegible]ted longitudinally by the walls. The box culv[illegible] and underground structures have been analyz[illegible] rigid frames for stresses due to dead-loa[illegible] live-load, and earth pressure.

At each of the airports studied, there are [illegible]en-sive and complex installations of pipe and [illegible]duits. Since complete and up-to-date data on the [illegible]e-ments are seldom available, the decision [illegible] made to use the same approach as that us[illegible] the analysis of pavements, and the DC-8 was [illegible] used as the criterion airplane. The resu[illegible] the analysis may be summarized as follows:

- For depths of cover of 1 to 2 ft, the B[illegible]7 imposes loads 5 percent greater than [illegible] imposed by the DC-8-55.
- For depths of cover of 2 ft to about 5 [illegible] DC-8-55 imposes the greater load.
- The depth of cover at which maximum [illegible] overstress on the pipe occurs is about [illegible] and, for this depth, the loads imposed [illegible]he B-2707 are about 8 percent greater th[illegible] those imposed by the DC-8-55.

The DC-8 and other aircraft exerting simil[illegible] loads have been operating at most of the airports [illegible]ied for over 5 years. The fact that no damage [illegible] pipe or conduit was reported during the investig[illegible] is indicative of proper selection of materia[illegible]

good construction practice. Since it would serve little useful purpose to remove and replace undamaged pipe in anticipation of imposed loads only 8 percent greater than those currently being borne without evidence of distress, it has been assumed that no cost will be incurred by the B-2707 for improvements to pipe and conduit.

4.2.3.4 Terminal Area

The goal in studies of the terminal area has been to examine the degree of flexibility open to the airlines for maneuvering and docking the B-2707 by conventional techniques. The operating criteria employed in studying the feasibility of maneuvering into and from a specific position were as follows:

- Allowance is to be made for a forward roll of 10 ft prior to stopping and a 10-ft forward roll prior to taxiing out.
- A minimum of 25-ft clearance from all fixed objects, retracted loading devices, and other aircraft shall be maintained while maneuvering and when docked, except that a minimum of 10 ft from nose to building will be permitted for nose-in parking.
- Retraction of the wings will not be necessary to gain required clearances.
- The maximum nose-wheel steering angle of 76 degrees may be employed for maneuvering.
- The nose, which is normally down for ground maneuvering, may be raised as required to clear low obstructions to maneuvering.
- When docked, the B-2707 will not interfere with vehicular travelways adjacent to terminal buildings and concourses.

Passenger loading evaluation must consider the imminent changes to be induced by proposed airplanes and traffic growth. Since the Boeing Model 747 and stretched versions of the DC-8 are being placed in service prior to the introduction of the B-2707, it is highly likely that many existing terminal facilities will have undergone extensive architectural remodeling. Hold rooms in concourses, for example, may require enlargement, and the concourses themselves may have to be widened. Since such alterations would probably be made even if the B-2707 were not developed, the costs involved are not properly attributable to it.

It is foreseen that passengers will normally be transferred between the B-2707 and the terminal building via second-story loaders. Alternate parking positions have been studied to determine the optimum mode of gate positioning for passenger handling. Final gate positions selected and shown in the report have been chosen to ensure taxiing clearance, and usage of existing loading bridges, while maintaining the capability of two-door loading.

Representative costs of alteration or replacement have been estimated for the various loaders in use at gate positions where the B-2707 can be readily parked. The costs of new loaders at new locations on the terminal face have also been estimated. Such costs are greater than those of a replacement loader by the amount required to provide power and an opening in the terminal face.

A wide variety of passenger-loading practices was observed at the airports included in the study. At some, all loading and unloading of large, subsonic jets is performed by movable ramps. More commonly, however, a mixture of practices is found. Typical of such situations is the one in which each airline has exclusive gates assigned to it and has been permitted to install loaders of its own choice at locations of its own choice. To achieve consistency in the allocation of costs per gate position, the following criteria have been adopted for the purposes of this report:

- At existing terminal facilities where there are now no loaders and where no equipment has as yet been selected for future installation, no passenger-loading costs are attributable to the B-2707. The basis for this reasoning is that future installations will, for the most part, be compatible with large subsonic jets and, therefore, with the B-2707 as well.
- The same reasoning holds true for proposed terminal buildings and for proposed extensions to existing terminal buildings.
- If at a particular concourse, satellite, or unit terminal building it is the current practice of a particular airline to perform all or most passenger loading by means of second-level loaders, then all costs incurred by providing the same capability at each B-2707 gate position shown for that airline are attributable to the B-2707.
- At concourses, satellites, or unit terminals where the airport operator or the airlines have installed loaders at only a few of many positions, second-level loading is not consid-

ered to be normal practice. Therefore, at those terminals, no loader costs are attributed to the B-2707. If an existing loader can be used, the costs of any required modifications to it, plus the costs of a second new loader are allocated to the B-2707.

Costs reflected in the summary are average per gate costs for the airport. The total is not shown, since it is dependent upon the total number of positions. Studies are continuing to determine a means of utilizing the additional passenger loading doors beyond the two forward doors used in this study.

Fuel will be a standard commercial kerosene of the same grade as that used by subsonic jet airplanes. Thus, the existing fuel storage and distribution systems may be used for both supersonic and subsonic airplanes.

The B-2707 has a usable fuel capacity of 54,790 U.S. gal. Fuel will be loaded through two illuminated underwing fueling stations, each with two nozzle connectors. The airplane is designed to accept 2000 gpm at a maximum pressure of 50 psi at the nozzle. At those airports where underground fuel supply lines are not installed, it will be practical to refuel the B-2707 from large tanker trucks. The designs of most existing underground systems have been based upon a maximum fueling rate of 1200 gpm per gate. In general, the B-2707 will occupy two current gate positions. Since the ideal flow rate of 2000 gpm for the B-2707 is less than twice the ideal flow rate of 1200 - 1600 gpm specified for the current subsonics, increases to the loop system sizes are not considered to be attributed to the supersonic transport.

Existing fuel hydrants will probably not be adaptable to the B-2707. It appears that the ASA standard 2-1/2-in. hydrant connection will have to be replaced by a 4-in. connection to satisfy the airplane fueling rate requirements. Where underground fueling systems are in place or firmly planned, the average costs of providing new hydrants and laterals have been calculated and attributed to the B-2707.

4.2.3.5 Blast Effects

The principal difference in relation to blast effects between the B-2707 and current subsonic jets is in engine thrust. While jet wake velocities are generally higher for the B-2707 (both GE and P&WA engines) than for current large subsonic jets, these differences, both at breakaway and at maximum thrust are not proportionately large, and the greater height of the B-2707 engines, as compared to those of current underwing engines, tends to offset the effects of higher velocities as related to vehicles and personnel on the ground.

In terminal areas, the principal operational difference anticipated is that the B-2707 will be towed or pushed somewhat farther from terminal faces and other aircraft and more frequently than is the present practice; this difference will be minor and will not significantly alter terminal operations.

The effects of B-2707 jet engine exhaust velocity and temperature on the runway surface have been investigated. Exhaust velocity impingement on the runway at maximum dry power is less than that caused by present subsonic airplanes. Temperatures will be slightly higher. Neither velocity nor temperatures at maximum dry power will affect concrete or asphalt runway surfaces. With augmented power, impingement exhaust velocities and temperatures are higher than current subsonic jets. However, no damaging effect to asphaltic runways is expected.

4.2.3.6 Runway Length Requirements

Takeoff and landing runway lengths were evaluated against the airplane performance requirements listed on Table 4-B. The combination of high-thrust engines and variable-sweep wings provided compatibility with all the anticipated use runways at the 15 airports studied.

4.2.3.7 Fire Rescue Equipment

Considerable research and development in aircraft fire rescue technology is in progress. The FAA and the military are engaged in studies and experimental programs designed to improve equipment response time and fire-fighting materials, capabilities, and techniques.

The advent of subsonic jets with passenger-carrying capacity comparable to the B-2707 is not expected to necessitate the development of new types of rescue equipment. Safety aspects of the B-2707 design including crash safety, emergency escape, and crash fire safety assurance will meet or exceed the requirements of FAA specifications. Valuable extra minutes of protection for occupants of the B-2707 may be gained from the temperature-resistant titanium fuselage. The arrangement and size of the exits permit evacuation of passengers in 90 seconds on the ground with all exits blocked on one side. Fire and rescue equipment beyond that available when the B-2707 is introduced into service is not anticipated.

Table 4-B. Runway Length Requirements

	Engines	
	P&WA	GE
FAR LANDING FIELD LENGTH (Flaps 20°/40°)		
Dry Runway	(Lengths in Ft)	
Normal Landing Wt		
P&WA - 378,000 lb	6,800	
GE - 384,500 lb		6,900
Max Design Landing Wt		
P&WA - 420,000 lb	7,400	
GE - 430,000 lb		7,500
Wet Runway per FAR 121.195 (d)		
Normal Landing Wt	6,900	7,000
Max Design Landing Wt	7,500	7,600
FAR TAKEOFF FIELD LENGTH		
(Max takeoff wt - 672,000 lb)	(Lengths in Ft)	
Full Augmented Power		
Standard day		
Sea level	7,300	7,000
2,000 ft elev	8,300	7,900
Standard day + 20°C		
Sea level	8,900	8,800
2,000 ft elev	10,200	9,900

In view of the fact that FAA safety standards have been met or exceeded, no costs for fire and rescue equipment have been included, unless specifically requested by the airport operator.

4.2.3.8 Airport Evaluations
Results of the application of the foregoing evaluation criteria to the 15 designated airports, along with appropriate aerial photographs, are included in subsequent paragraphs of this report. Blast effects, runway length, and fire and rescue equipment are not treated for individual airports, unless specifically requested by the airport operator.

4.3 ANCHORAGE INTERNATIONAL AIRPORT

4.3.1 Evaluation of Pavements
All pavements are of flexible construction and are supported by a sand filter course up to two feet thick. Although subgrade construction of this kind is non-plastic, the airport operator reports that extensive areas of the subgrade hold water and are susceptible to frost. The reports recommend the use of an FAA subgrade classification of F6. The FAA method of pavement design with an F6 subgrade classification results in a required flexible pavement thickness for the DC-8 of 34 in., for the B-2707, the requirement is 32-in. Runway 6-24, 10,600-ft long, was constructed with a number of different pavement cross-sections, none less than 35-in. in total thickness. Most terminal area and taxiway pavements are 37-in. thick.

Because the B-2707 has a pavement thickness requirement less than the DC-8-55, no costs have been attributed to the B-2707.

4.3.2 Requirements for New Pavements
The geometry of all paving fillets was taken from plans made available by the airport operator and verified from an aerial photograph. Included in the investigation were 25 fillets, 14 of which require improvement. The general assumptions and criteria for the present evaluation may be found in Par. 4.2.3. The specific assumptions made for the investigation of the fillets at Anchorage are as follows:

a. Runway 13-31 will be extended as shown on Fig. 4-6 prior to the introduction of the B-2707. As a result, its exit taxiways will be used routinely by the B-2707.

b. Cost estimates given have been based upon the conservative assumption that existing fillet radii will only be improved when required by the introduction of the B-2707.

c. The terminal apron expansion proposed on the Airport Master Plan will have been accomplished prior to the introduction of B-2707 operations. As a result, improvements to the fillets at the periphery of the existing terminal apron need not be considered.

The total costs for pavement improvements as listed are attributable to the B-2707. They have been estimated using current construction costs; the results are summarized in Par. 4.3.5.

At Anchorage International Airport, there are presently three holding aprons; one near the threshold of runway 13 and one at each end of runway 6-24. As shown on Fig. 4-6, runway 13-31 is planned to be extended on both ends. It has been assumed that the extension of runway 13-31 will include holding aprons satisfactory for B-2707 use.

Runway 6. Because the holding apron at the southwest end of the primary runway does not meet the criteria stated in Par. 4.2.3, the costs of extending it have been allocated to the B-2707. The north edge of the apron cuts into the slope of a low hill, but its west side has been built on a shallow fill. The assumption has been made that the apron will be widened to the west and will, as a result, incur only minor costs for grading work.

Runway 24. According to the criteria discussed in Par. 4.2.3, the apron dimensions are adequate.

4.3.3 Evaluation of Structures
From the available data, it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions as defined in Par. 4.2.3. Therfore, they are compatible with the B-2707.

4.3.4 Terminal Area Considerations
Anchorage International Airport plans a complete revision of its terminal area. Recently completed is a hexagonal-shaped satellite currently being served from the existing building by a temporary connection through the finger pier. Construction of the new finger pier indicated on Fig. 4-7 will provide a permanent connection to the central building. The three nose-in loading positions shown are based on an initial anticipated requirement for forward door loading only. These positions, shown on Fig. 4-7 have been found satisfactory, with respect to maneuvering, adaptability to different gate arrangements, and effects upon adjacent gate positions.

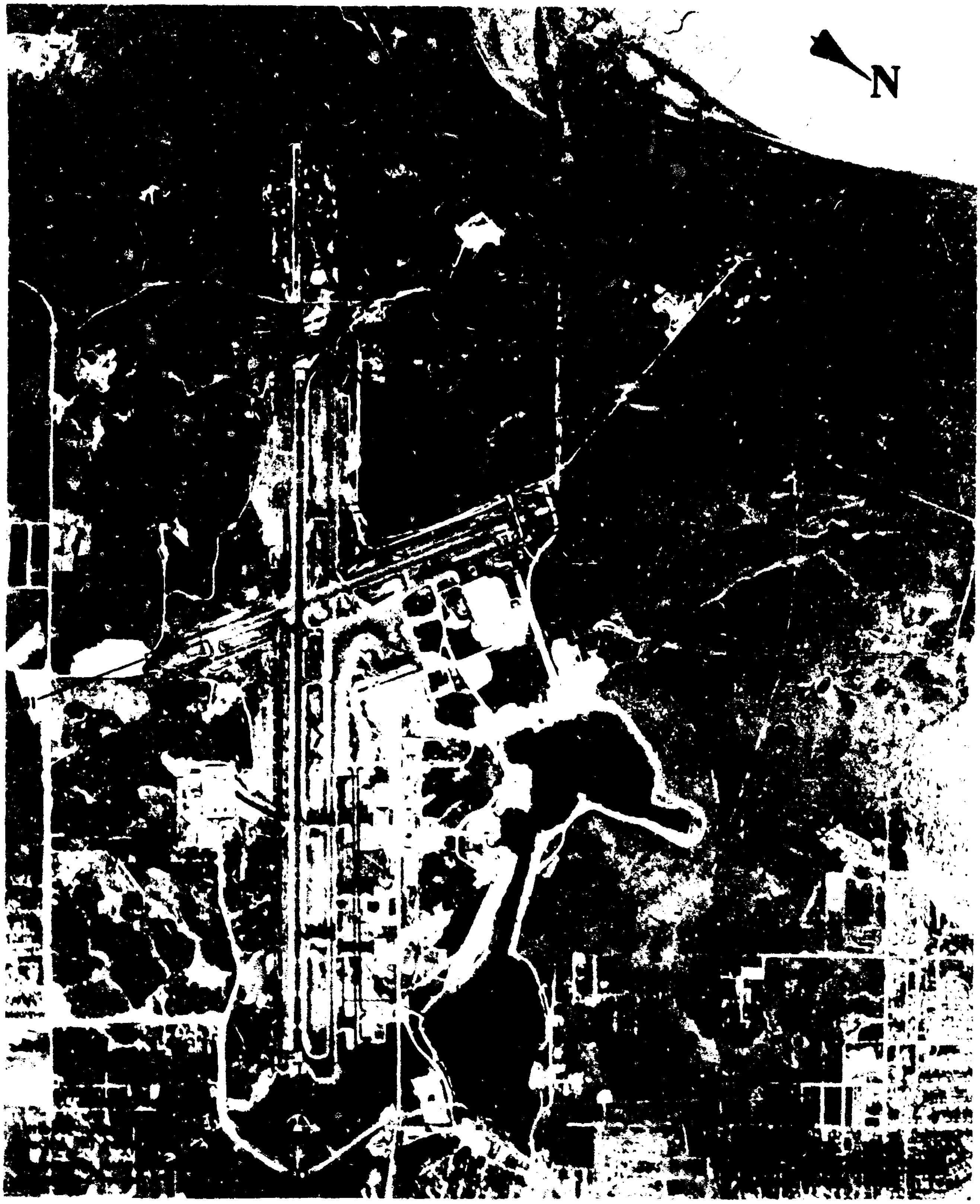


Figure 5–6. Anchorage International Airport

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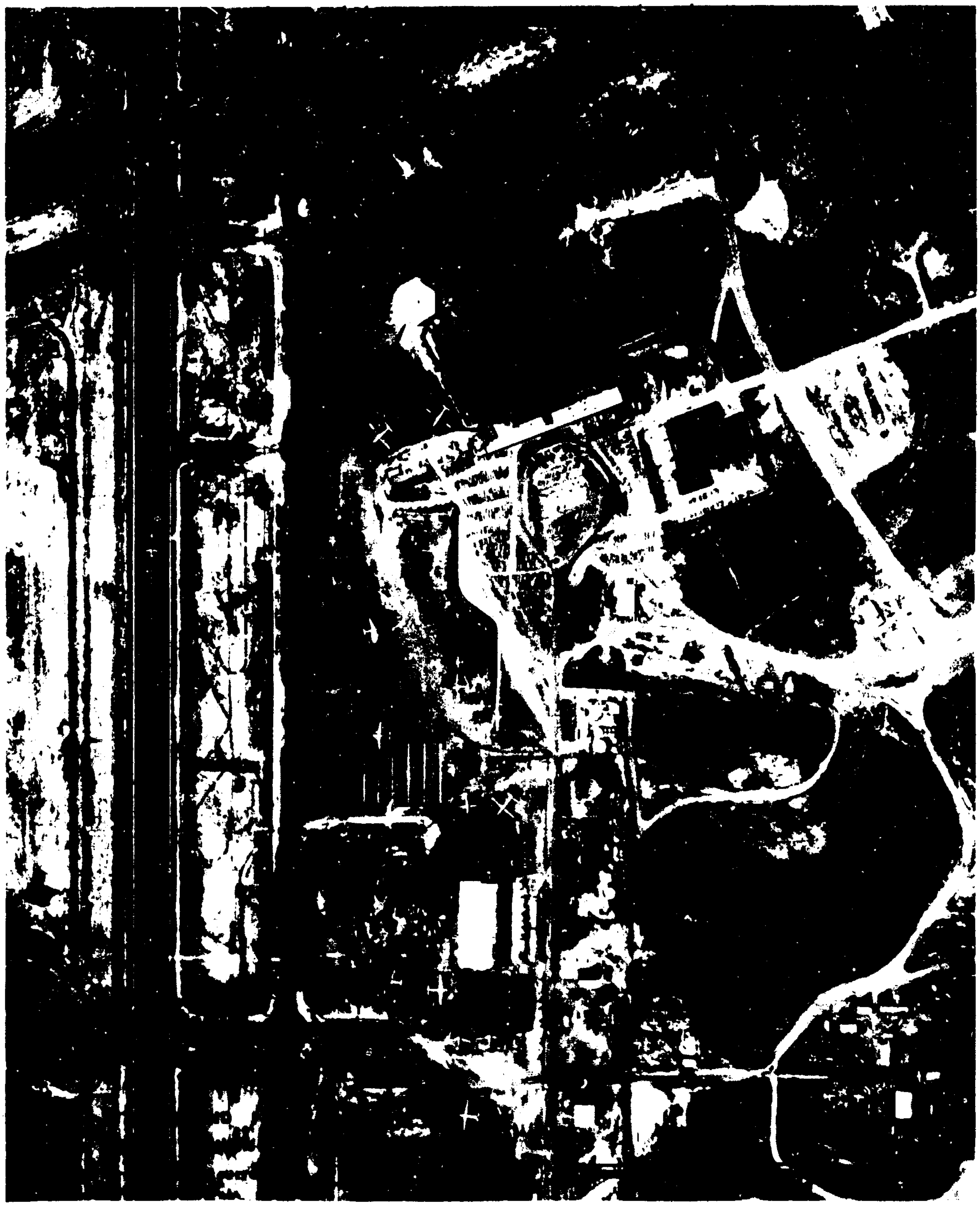

Figure 4-7. Anchorage Terminal Area

V4-B2707-1

A single fixed-length loader (swing-type) has been installed on the new satellite. This loader is compatible with the B-2707 for forward-door loading. No costs have been allocated for the other two positions shown, on the assumption that any loaders that may be installed in the future will be of adequate length.

Underground fueling at Anchorage consists of one service point at the north end of the old terminal and a system recently installed to serve the new satellite area. The fuel systems will require modifications to satisfy B-2707 requirements. The cost has been estimated and included in the summary.

4.3.5 Estimated Costs

a. Lump Sum Items

Modification of 14 fillets:	
Full-strength pavement at \$8 per sq yd	\$30,000
Shoulder pavement	27,000
Revisions to lights and signs	17,000
Widening of runway 6 holding apron:	
Full-strength pavement at \$8 per sq yd	8,000
Shoulder pavement	5,000
Revisions to lights	1,000
Total Estimated Costs	\$80,000

b. Unit Costs per Gate Position

Fuel system modification	\$20,000

4.4 FRIENDSHIP INTERNATIONAL AIRPORT, BALTIMORE

4.4.1 Evaluation of Pavements

Except for concrete inlays in the terminal-area apron, all pavements at the Baltimore Friendship International Airport are flexible. Original pavements were composed of a 5-in. granular subbase, 7-in. bituminous base, and a 3-in. surface course. In 1964-1965, all such pavement was given a leveling course, which varied in thickness from 0 to 4 in., with a 1-1/2-in. overlay. Thus, the original pavements range from 16-1/2 to 20-1/2 in. in thickness. Newer flexible pavements are similar to those constructed in 1950, except that the subbase courses are 10-in. thick, and are not overlaid. Thus, their total thickness is 20 in.

For use with the FAA flexible pavement design procedure, an FAA subgrade classification of F1 is recommended by engineers of the Department of Aviation. For use with the Corps of Engineers method, a minimum value of CBR 20 is judged to be reasonably conservative by the airport operator and his consultants. Using these data, the FAA method of calculation results in DC-8-55 and B-2707 requirements of 15 and 13.5 in. of pavement, respectively. By the Corps of Engineer's method, 18 and 20 in. are required. For purposes of the study, the Corps of Engineers' pavement design method has been applied, resulting in selection of the B-2707 as the critical airplane. All of the newer pavements are 20-in. thick and are presumed adequate.

As noted, the older payments now range in thickness from 16-1/2- to 20-1/2-in. For the B-2707, the 20-1/2-in. thickness corresponds to the pavement requirements of a subgrade having a CBR value fractionally lower than 20; while the 16-1/2 in. thickness corresponds to CBR 26. It is logical to assume that the recommended minimum CBR value represents the subgrade conditions underlying those areas of older pavement that required 4 in. of leveling courses when the 1-1/2-in. overlay was placed. Since the pavements in such areas are now 20-1/2-in. thick, the B-2707 would impose no additional thickness requirements on the weakest subgrades. It is reasonable to assume that higher subgrade strengths generally occur in areas that underwent little or no settlement, in which case the 16-1/2-in. thick pavement would be adequate for the B-2707.

4.4.2 Requirements for New Pavements

The geometry of all paving fillets were taken from plans made available by the airport operator. Included in the investigation were 36 fillets, 6 of which require improvement, and 7 curved taxiways, of which 4 will require improvement. The general assumptions and criteria for the pavement evaluation may be found in Par. 4.2.3. The specific assumptions are as follows: (1) because of planned extensions (Fig. 4-8) to runways, existing exit taxiways nearest present landing thresholds will be used routinely by the B-2707; (2) the present investigation takes into account only those fillet improvements that are firmly planned for 1967; and (3) extensive revisions are planned for the terminal apron and its peripheral taxiway (Fig. 4-9). It is assumed that these revisions will have been accomplished prior to the introduction of the B-2707; hence, certain existing fillets need not be investigated for compatibility.

Figure 4-8. Friendship International Airport

V4-B2707-1

Figure 4-9. Friendship Terminal Area

V4-B2707-1

The total costs for the improvements to the pavements described are attributable to the B-2707. The estimates are based upon current construction costs, and the results are summarized in Par. 4.4.5.

There are three major holding aprons at Friendship International Airport. A fourth is being constructed at the runway 33 threshold. When this construction is completed, there will be holding aprons at each end of runway 10-28 and runway 15-33. Each appears to be adequate by the criteria stated in Par. 4.2.3. There are small paved areas used for holding, near the threshold of runways 4 and 33. Another such area is located adjacent to taxiway G, near the end of runway 10. Information from the Department of Aviation indicates that these areas will not be used by the supersonic transport.

It is the opinion of the airport operator that rigid-pavement inlays would be required at the B-2707 gate positions. Accordingly, a cost-per-gate-position has been estimated.

4.4.3 Evaluation of Structures

Two box culverts required investigation. A 7-by 5-ft reinforced-concrete structure, passes beneath runway 10-28, with a depth of cover of about 18-ft. A 9-by 6-ft, 7-in. reinforced-concrete structure passes beneath the east-west taxiway with a depth of cover of about 22-ft. For both structures, the critical section was mid-point of the top slab of the box. The calculated stresses induced in reinforcement and in concrete were less than the allowables.

There are a number of drainage structures so located in the airfield pavements at Baltimore that they are subjected directly to plane loads. Each of the different types was investigated to determine its adequacy for supporting the maximum load of the B-2707. The investigations included grates, supporting beams, and footings. All grates and their supporting beams would be under-stressed by the B-2707's imposed live load with 30 percent impact factor. Stresses in footings are within the design limits, as are the soil bearing pressures.

All pipes and conduits beneath airfield pavements are within the range of acceptable conditions stated in Par. 4.2.3.

4.4.4 Terminal Area Considerations

The terminal area at Friendship International Airport follows the central terminal and finger pier concept. Three separate buildings connected by pedestrian concourses compose the center of the terminal area. Two finger piers have already been built. Extensions for the two existing piers and construction of a third are in the planning stage. A Y configuration has been assumed for the extension of the north pier. Eight B-2707 positions have been indicated in Fig. 4-9. Internal parking is not feasible due to the restriction of maneuvering room, and the encroachment on the potential parking positions of smaller airplanes.

All loading and unloading of passengers at Baltimore is presently done by means of mobile ramps. Ten swinging fixed-length type loaders are currently being purchased for installation. Considering that the B-2707 positions shown on Fig. 4-9 are all at proposed future pier locations, it is anticipated that the equipment now on order will adequately accommodate the B-2707. No cost has been assessed against the B-2707.

Airplane fueling is now performed with mobile tenders. The tenders are operationally flexible and can be furnished in quantities sufficient to supply the B-2707.

4.4.5 Estimated Costs

a. Lump Sum Items

Modification of 6 fillets and 4 curved taxiways:	
Full-strength pavement at $7 per sq yd	$11,000
Revisions to lights and signs	8,000
Total Estimated Costs	$19,000

b. Unit Cost Per Gate Position

Terminal Apron Inlays	$18,000

4.5 LOGAN INTERNATIONAL AIRPORT, BOSTON

4.5.1 Evaluation of Pavements

Logan International Airport (Fig. 4-10) is constructed on a hydraulic clay fill having an FAA subgrade classification of F7. The hydraulic fill was placed on top of an organic silt layer. The intention was to have the fill displace the silt and come to rest on an underlying layer of firm clay but the organic silt has not been fully displaced. As a result, there have been settlement problems at the airport.

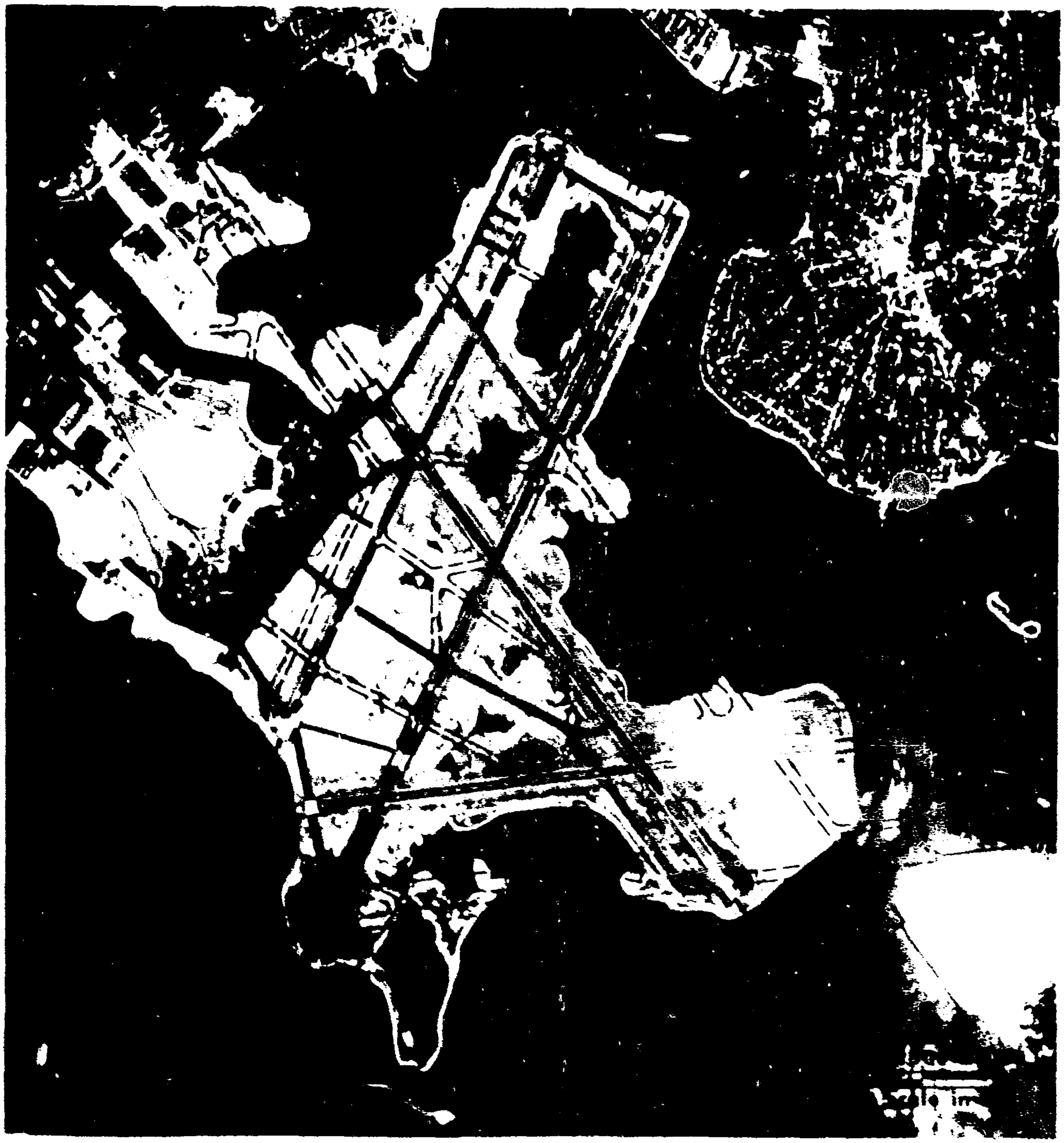

Figure 4-10. Logan International Airport

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All existing pavements are flexible. Except in the original terminal area, where a 10-ft-thick layer of pit-run gravel was placed prior to paving, the 39-in.-thick pavements were constructed directly on the clay fill. Leveling courses and an overlay added a minimum of 2-in. to the runway. In the areas of maximum settlement, the total thickness of flexible pavement added was as high as 27-in. Some sections of taxiways that developed settlements have also been corrected. Elsewhere, the taxiways have received seal coats. The critical pavement areas in the terminal and the pavements at aprons and taxiway intersections have been sealed with a tar-rubber compound which resists deterioration from fuel spillage. Visual inspection showed all the pavements to be in good condition with some minor longitudinal rutting in one of the taxiways.

The airport's pavements were designed in accordance with the equivalent single wheel load method developed by the Civil Aeronautics Adminstration. For the design of critical pavement sections, the present FAA flexible pavement design system results in a thickness requirement for the DC-8-55 of 39-in.; for the B-2707 the requirement is 37-in. On this basis, the costs of any pavement strengthing would not be attributable to the B-2707.

New terminal apron construction in the current expansion program is 15-in.-thick portland cement concrete. In some areas, it is being placed directly on old pavements; in others, on a 24-in. gravel subbase. Aprons so constructed will be compatible with the B-2707.

4.5.2 Requirements for New Pavements
Included in the investigation were 44 fillets and 3 curved taxiways, of which 4 fillets require improvements. The geometry of the fillets was taken from plans made available by the airport operator and verified from an aerial photograph.

The total costs for the pavement improvements listed are attributable to the B-2707 and were estimated, using current construction costs. The general assumptions and criteria for the pavement evaluation may be found in Par. 4.2.3. The terminal apron expansion at Logan International Airport shown on Fig. 4-11 will be completed prior to the introduction of B-2707 operations, eliminating the need for improvements to the fillets at the periphery of the existing terminal apron.

Results of the investigation of the holding aprons at Logan International Airport are provide below.

a. Runway 4R Holding Apron. This apron does not meet the criteria of Par. 4.2.3. A widening of approximately 30-ft to the south is necessary for B-2707 usage, putting the south edge of the expanded apron immediately adjacent to an existing maintenance roadway. This action will require the relocation of approximately 800-ft of perimeter maintenance roadway. Estimated cost for this relocation, including paving, filling into Boston Inner Harbor, and rip-rap slope protection, is included in Par. 4.5.5.

b. Runway 15R and Runway 27. Holding aprons for these runways satisfy the requirements of Par. 4.2.3.

c. Runway 33. The apron at runway 33 threshold now consists of a section of pavement placed for planned runway 9R-27L. Widening will be necessary if 9R-27L is not constructed prior to the instroduction of B-2707 service. Costs have been estimated for the appropriate widening and necessary relocations of lights and signs.

4.5.3. Evaluation of Structures
Two storm-water drainage structures were investigated for B-2707 loadings. These structures pass beneath taxiways connecting runway 4L-22R and the east side of the terminal apron.

A double 3-by 4-ft reinforced-concrete box culvert supported on piles carries the flexible pavement of one taxiway directly. A check of the pile loads and the stresses in the concrete and reinforcing steel shows that the structure is capable of carrying the B-2707.

A pile-supported, concrete-bedded, 34-in.-diameter concrete pipe culvert carries storm-water runoff beneath the south taxiway. The minimum cover on the section of the pipe subjected to aircraft loadings is about 5.5-ft. Pipe of the lowest strength (Class I) and having a Class A bedding condition was assumed for investigation. The pipe in its bedding is more than adequate to sustain the B-2707 live loads. The adequacy of the piles is questionable; however, the B-2707 imposes a total load only 5 percent in excess of that imposed by the DC-8-55. No costs for strengthening the culvert supports have been attributed to the B-2707.

All other pipes and conduits beneath the airfield pavements are within the range of acceptable conditions stated in Par. 4.2.3

Figure 4–11. Logan Terminal Area

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4.5.4 Terminal Area Considerations
The current expansion program will greatly increase the number of airport gate positions. Two new terminal buildings and loading facilities on each of the four T-shaped existing piers is scheduled. A new terminal building is under construction in the southwest area of the terminal apron. The three future piers are planned for both linear and satellite loading. Airplane parking positions are also arranged along the faces of the terminal buildings and their connecting concourses. Fifteen parked B-2707's have been shown at the outer gate positions of the existing and future piers. The positions shown at existing T piers have been investigated on the basis of their anticipated future development. It can be demonstrated that interior positions are also feasible.

The plans for second-level loading are presently incomplete. If maneuvering clearances and sill heights of future airplanes are considered in the selection of loading equipment, the B-2707 gate positions shown on the terminal area exhibit can be adapted for simultaneous two-door passenger loading. No costs are chargeable to the B-2707 for the adaptation of passenger-loading devices until plans for loading arrangements become better defined.

Aircraft fueling is now performed with mobile tenders which are operationally flexible and capable of supplying the fuel requirements of the B-2707.

4.5.5 Estimated Costs

Lump Sum Items	
Modifications to 4 fillets:	
Full-strength pavement at $9 per sq yd	$11,000
Shoulder pavement	8,000
Revisions to lights and signs	5,000
Widening of runway 33 holding apron:	
Full-strength pavement at $9 per sq yd	19,000
Shoulder pavement	5,000
Revisions to lights	2,000
Widening of runway 4R holding apron:	
Full-strength pavement at $9 per sq yd	17,000
Shoulder pavement	7,000
Revisions to lights	3,000
Relocation of roadway	50,000
Total Estimated Costs	$127,000

4.6 O'HARE INTERNATIONAL AIRPORT, CHICAGO

4.6.1 Evaluation of Pavements
The layout of present and proposed pavement is shown on Fig. 4-12. Both rigid and flexible pavements have been constructed at O'Hare International Airport. In some places, the rigid pavements have received bituminous overlays. Engineers of the Chicago Department of Aviation recommend the use of a subgrade modulus of reaction of k = 100 for the design of rigid pavements and an FAA soil strength classification of F4.

The critical areas at the ends of runway 14R-32L, sections of the taxiway parallel to it, taxiways T-1, T-2, T-3, and T-7, and the terminal area apron consist of 15-in.-thick concrete pavement over 12-in. of crushed-stone base. The modulus of reaction recommended for use on top of the stone base is k = 190. For these conditions, it is calculated that the fully loaded DC-8-55 induces flexural stresses about 6 percent higher than the recommended maximum allowable, which is 330 psi. The B-2707, on the other hand, would induce stresses about equal to the allowable.

The noncritical portion of runway 14R-32L is an 11-in.-thick concrete pavement with a maximum allowable flexural stress of 330 psi. The calculated stresses induced by the DC-8-55 and the B-2707 in this pavement are, respectively, 51 percent and 44 percent higher than the allowable recommended. Because the B-2707 is less critical than the DC-8-55, no pavement upgrading costs have been attributed to the B-2707. Runway 14L-32R and taxiways serving it are 12-in.-thick concrete pavements. Asphaltic concrete overlays ranging in thickness from 2- to 4-in. have been placed over much of the original construction. The flexural stresses induced in all of these pavements are again somewhat higher for DC-8-55 loadings than for B-2707 loadings. The costs of any future pavement improvements would not be attributable to the B-2707.

Figure 4-12. O'Hare International Airport

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The FAA method was used to design O'Hare's flexible pavements, which are 27- and 29-in. thick. Pavement thickness requirements for the DC-8-55 and the B-2707 are 25.5-in. and 24-in., respectively. Therefore, the DC-8 is controlling and both airplanes are compatible with the existing flexible sections.

4.6.2 Requirements for New Pavements
Included in the investigation were 101 fillets and 5 curved taxiways, of which 11 fillets required improvements. The geometry of the fillets was taken from plans made available by the airport operator and verified by aerial photography. The general assumptions and criteria for the pavement evaluation are found in Par. 4.2.3. The specific assumptions made are as follows:

a. Existing runways 9-27 and 4-22 will be decommissioned prior to the introduction of B-2707 operations.

b. Turns of 180 degrees between the inner and outer circular apron taxiways are rarely made, as are consecutive 90 degree turns made in opposite directions between these two taxiways.

The total costs for the improvements to the pavements described above are attributable to the B-2707. These costs have been estimated using current construction costs; the results are summarized in Par. 4.6.5.

The holding aprons at the thresholds of runway 14R-32L are adequate for the B-2707 by the criteria stated in Par. 4.2.3. The three other aprons that presently exist are inadequate; however, they will not be used for holding. No costs have been estimated for expansion of O'Hare's holding aprons.

4.6.3 Evaluation of Structures
A circumferential taxiway bridge is presently being constructed over the airport access highway. While this structure is designed for a 600,000-lb airplane, the load distribution from the 675,000-lb B-2707 is such that the structure and the airplane are compatible.

All pipes and conduits beneath the airfield pavements are within the range of acceptable conditions stated in Par. 4.2.3. Therefore, they are compatible with the B-2707.

4.6.4 Terminal Area Considerations
The terminal area at O'Hare International Airport (Fig. 4-13) is basically patterned on the central terminal and finger pier concept. The central domestic terminal is actually two buildings branching from a circular central service core. At some distance from the domestic terminal, but connected to it by concourses, is the international terminal. Maneuverability studies indicate that there are about 22 parking positions where the B-2707 could be readily accommodated. The finger pier configuration readily lends itself to the canted parking position. This has the inherent advantage of minimizing the need for modifications to existing passenger loading devices, the required lengths of new loaders, and the extent of modification to underground fueling systems. No parking studies were made of the two linear concourses proposed in the master plan of the terminal area because of the tentative status of planning.

With the typical canted parking position shown, it is possible to utilize the swinging-telescoping bridges existing at some locations. These bridges would require adjustment to their vertical articulation capability in order to reach the second door sill of the B-2707.

At pier D, three existing swinging-telescoping loaders could be modified and utilized for the two end-of-pier positions. For the westerly end position, an existing loader might be modified and utilized at the second door. Similarly, the two interior positions could be served by three existing loaders. One existing non-telescoping loader might be relocated to service the forward door of the westerly interior position.

The end positions at piers E and F and the six positions at H and K require new loaders. All three parking positions at pier G can be served with modified existing equipment.

A loop fuel system having a combined capacity of 46,300 gpm serves all concourses except the International Arrivals Building, where the system has been abandoned. The typical jet gate position is served by two sets of underwing hydrants, each of which is connected to a different supply loop.

At each of the B-2707 positions shown on Fig.4-13, two new fueling hydrants are considered necessary to permit the B-2707 to be refueled at its maximum rate. To serve these hydrants, new laterals have been included in the cost estimates.

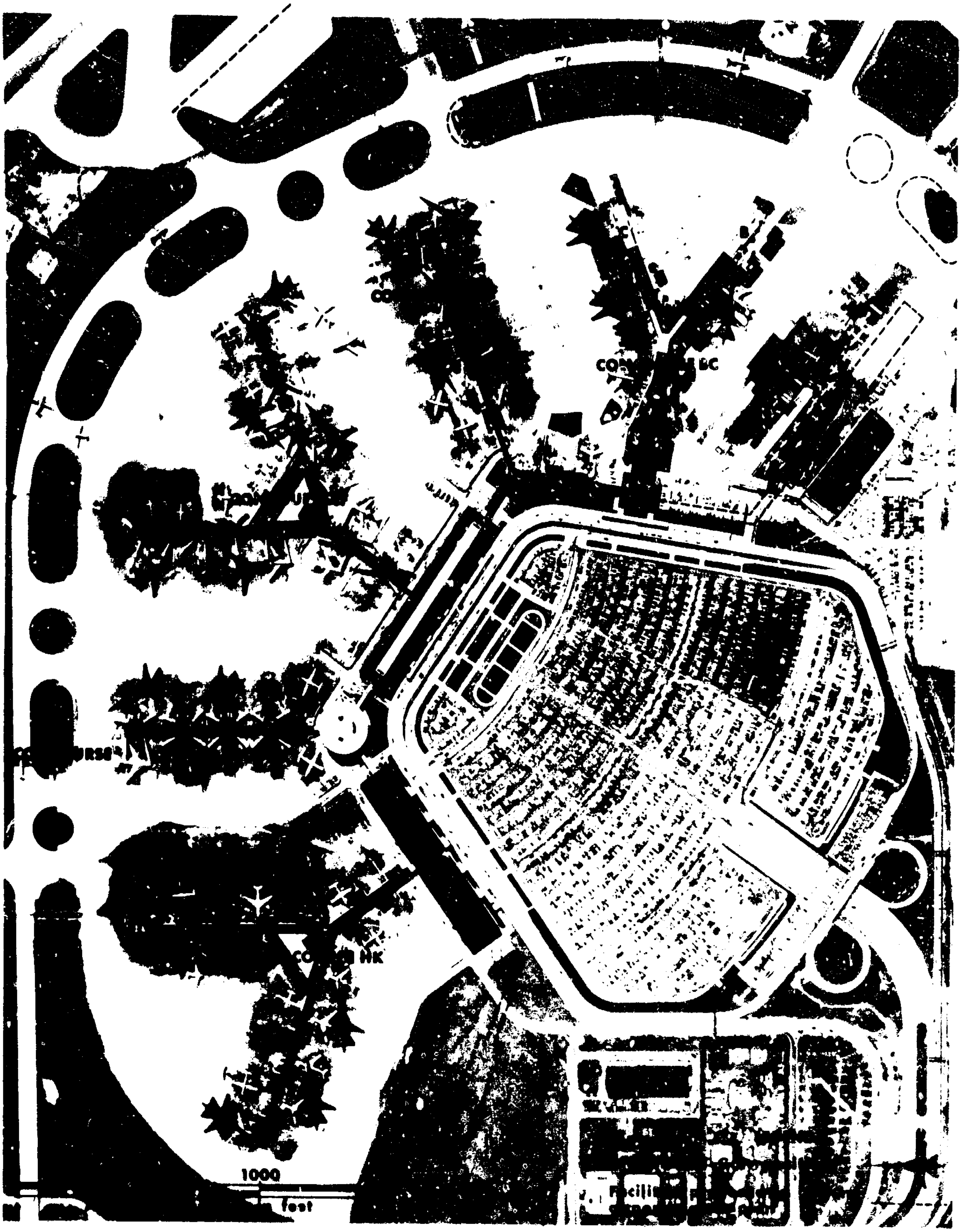

Figure 4–13. O'Hare International Terminal Area

4.6.5 Estimates Costs

a. Lump Sum Items

Modification of 11 fillets:

Full-strength pavement at $10 per sq yd	$49,000
Shoulder pavement	25,000
Lighting revisions	14,000
Total Estimated Costs	$88,000

b. Unit Costs per Gate Positions

Passenger loading devices	$50,000
Fuel system modification	$12,000

4.7 DETROIT METROPOLITAN WAYNE COUNTY AIRPORT

4.7.1 Evaluation of Pavements

The layout of present and proposed pavement is shown in Fig. 4-14. All pavements at Detroit are rigid and in excellent condition. The runways consist of 13-in.-thick slabs in the critical sections and 11- in.-thick slabs in the noncritical interior sections. Taxiways and aprons are 12-in. thick. The subgrade modulus recommended for slab design and analysis is k = 200. The maximum allowable concrete flexural stress is 350 psi. When operated on any of these pavements at their maximum weights, both the DC-8-55 and the B-2707 induce flexural stresses greater than the allowable. However, the DC-8-55 imposes slightly greater stresses in every case. Since the pavements are apparently compatible with the aircraft operating there today, it is anticipated that they will also sustain the B-2707.

4.7.2 Requirements for New Pavements

Of the 77 fillets and 2 curved taxiways investigated, 22 fillets and both curved taxiways will require improvement. The geometry of all paving fillets was taken from plans made available by the airport operator and verified from an aerial photograph. General assumptions and criteria leading to the standards adopted for the present evaluation are in Par. 4.2.3. All costs associated with such modifications have been estimated and charged to the B-2707. Fillet modifications, where required to accommodate the B-2707, are minimized by the 200-ft width of existing runways.

There are holding aprons at each threshold of runway 3L-21R, the instrument runway at Detroit. Each is connected to the runway by a 75-ft wide, curved taxiway. The apron at runway 3L will require a simple widening to meet the requirements outlined in Par. 4.2.3; the cost of this improvement will be charged to the B-2707. Immediately adjacent to the terminal apron is the holding apron for runway 21R which has the same dimensions as the apron at the opposite threshold. Planned additional paving adjacent to the proposed satellite on finger G, will provide sufficient pavement for holding and taxiing operations.

The geometry of the taxiway, holding apron, and terminal apron pavements was checked for the following concurrent events: (1) a current large subsonic jet parked nose-in at the end of the United Air Lines Satellite; (2) a B-2707 with wings fully extended taxiing on the apron past the parked jet; (3) another B-2707 with wings fully extended parked on the existing holding apron; (4) a current, large subsonic jet taxiing on the taxiway paralleling runway 3L-21R. Adequate operational clearances can be maintained without any revision of the pavement geometry in spite of this unlikely concentration of traffic.

4.7.3 Evaluation of Structures

A simple span bridge over a storm-water drain is located about 2,300 ft from the threshold of runway 3L. The 300-ft-wide section and 125-ft-wide section supporting runway 3L-21R and its parallel taxiway, respectively, were designed for a gross weight of 300,000 lb. The design load was a DC-8 with 150,000 lb on each 4-wheel truck. Detailed analysis of the bridge design shows it to be adequate for the B-2707.

All pipes and conduits beneath airfield pavements are characterized by the range of acceptable conditions stated in Par. 4.2.3 and are compatible with the B-2707.

4.7.4 Terminal Area Considerations

The layout of Detroit's passenger terminal employs a modification of the unit terminal concept. When the current expansion is complete, passengers will be processed in two separate terminal buildings located near the ends of a linear building arrangement. The two terminals and the central services building between them will be connected by a passenger concourse from which four of the six loading fingers will extend. (A seventh finger, which is shown on the master plan of the terminal area, would also extend from the linear concourse.)

Studies of the existing six fingers with their proposed modifications have shown canted and parallel parking modes to be preferable to the nose-in mode. All eleven B-2707 parking positions, as shown on Fig. 4-15, were studied on the basis of

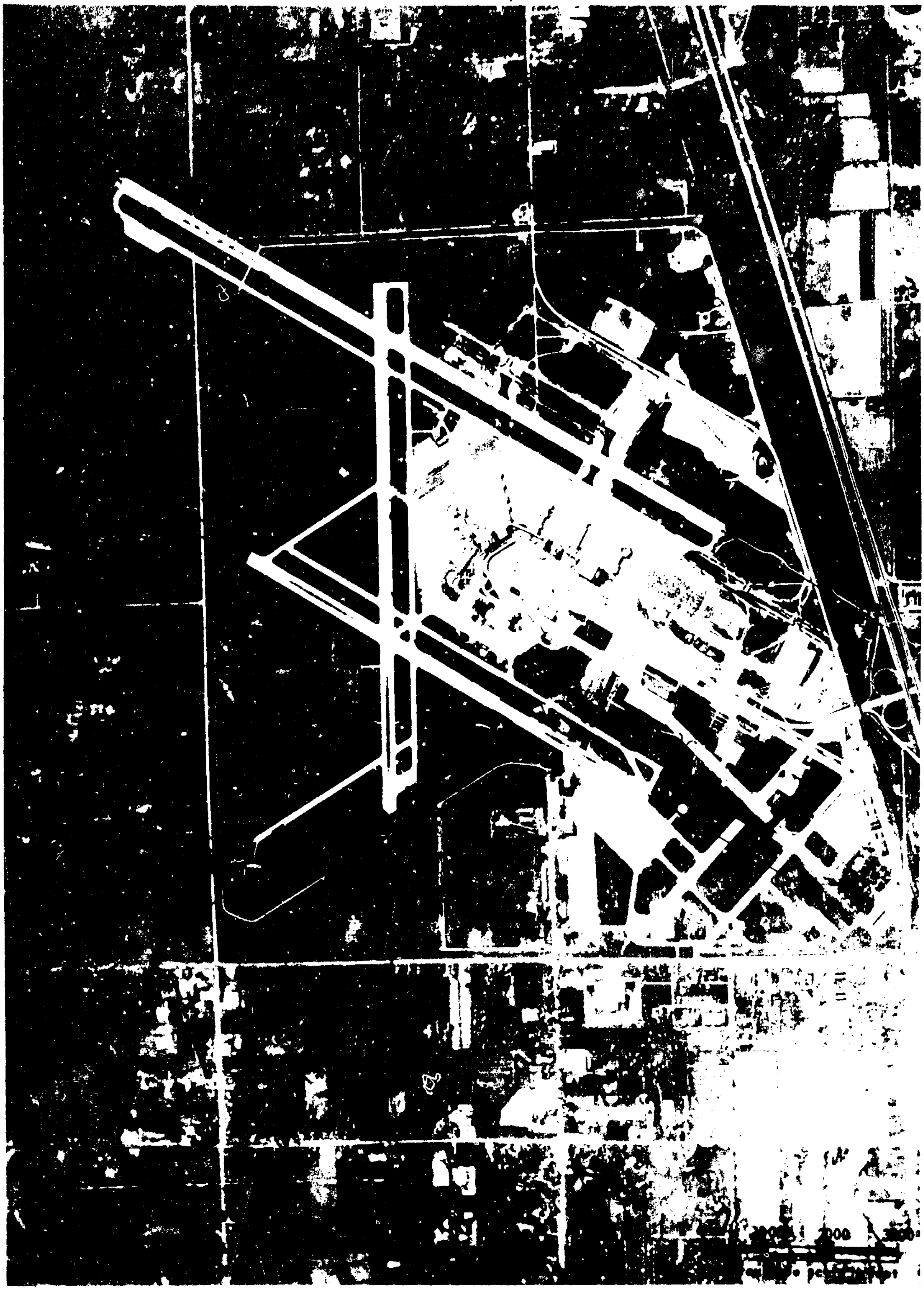

Figure 4–14. Detroit Metropolitan Wayne County Airport

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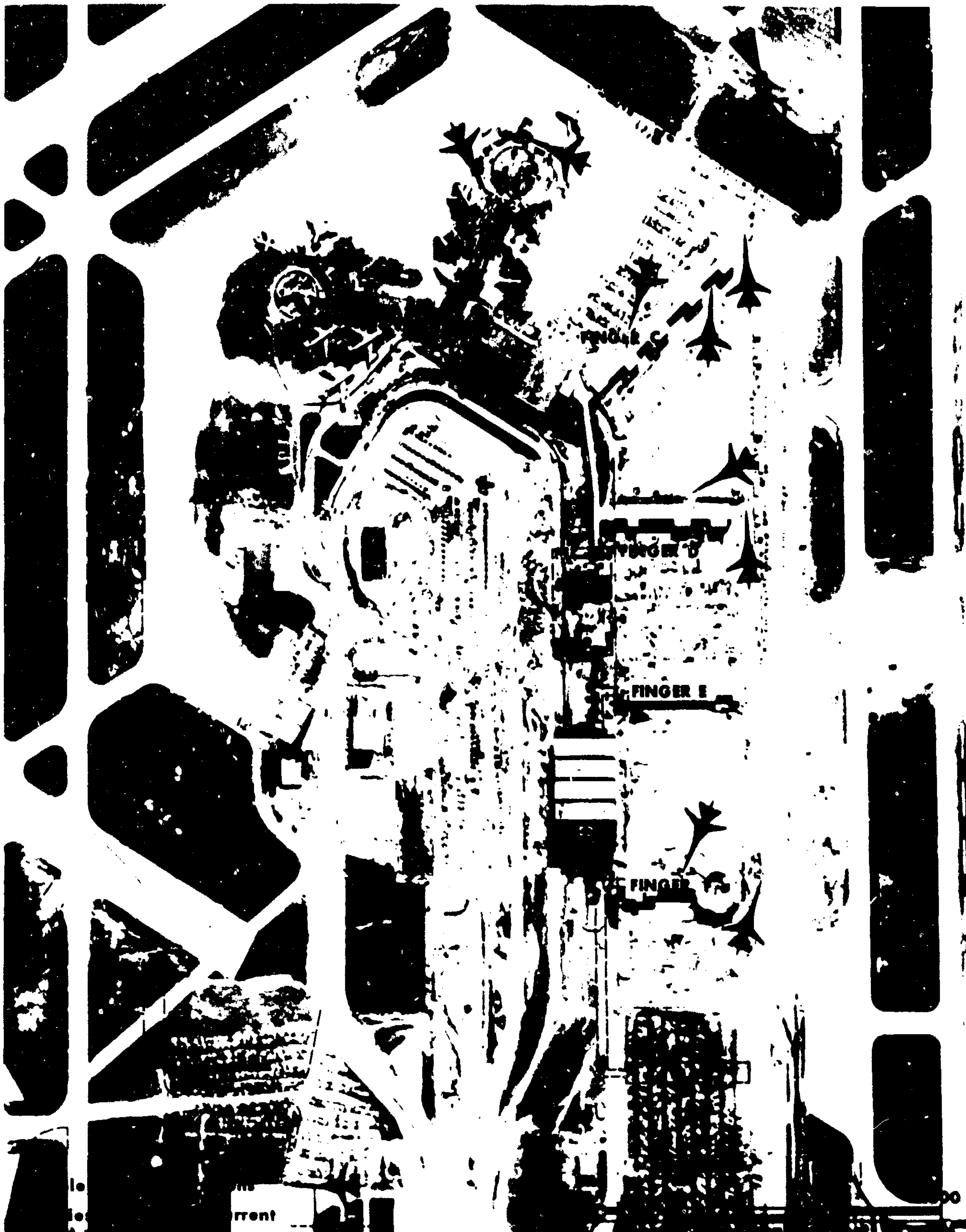

Figure 4-15. Detroit Terminal Area

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feasibility for maneuvering and docking by conventional techniques. Results of parking studies showed that fingers A, B, C, D, and F will accommodate the B-2707. Two positions may be occupied simultaneously at piers A, B, D, and F, and three at pier C. Pier E, a single-story building planned for local service airlines, was not considered for B-2707 docking. Finger G parking studies were not made because of the tentative status of future plans. The particular arrangements selected have been investigated for feasibility of convenient maneuvering, effects on the availability of adjacent gate positions, and adaptability to existing gate arrangements and loading procedures. All suggested modifications to presently planned loading facilities will result in equipment which will be common to the B-2707 and to the subsonic jets.

Swinging-telescoping bridges predominate over the variety of passenger loading devices. The existing swing-type nose-loading bridges at finger pier A (Fig. 4-15) can be vertically modified to serve the westerly position indicated at that location. For the easterly position, one new loader will be required. At finger pier B, two existing swinging-telescoping loaders can be modified to serve the position west of the pier. At the easterly position, one existing loader can be modified and utilized for the second door. For the forward door at this position, a new loader will be required. The end position for finger pier C will require two new loaders. A similar treatment can be applied to the position on the north side of the pier, where existing nose-loaders are not compatible with the B-2707. For the southerly positions shown, one existing loader can be modified vertically and one new swinging-telescoping loader will be required. The end position indicated at pier D can be served if the existing loaders are modified. The remaining position will require one new swing-type loader for the forward door and a vertical adjustment to an existing loader to serve the second door. At finger pier F, four swing-telescoping loaders will be required to service the two positions shown on Fig. 4-15. The existing nose-loaders are inadequate for the B-2707, and modification is not deemed feasible.

With the exception of United Air Lines, airlines serving Detroit presently fuel with trucks capable of servicing the B-2707. United Air Lines has an underground fueling system at finger F. The parking arrangement (Fig. 4-15) will require the addition of four hydrants at two gate positions for B-2707 compatibility.

4.7.5 Estimated Cost

a. Lump Sum Items

Modification of 22 fillets and 2 curved taxiways:	
Full-strength pavement at $12 per sq yd	$74,000
Shoulder pavement	12,000
Revisions to lights	31,000
Widening of runway 3L holding apron:	
Full-strength pavement at $12 per sq yd	8,000
Revisions to lights	2,000
Total Estimated Costs	$127,000

b. Unit Costs Per Gate Position

Passenger loading devices	$50,000
Fuel system modifications	8,000

4.8 HONOLULU INTERNATIONAL AIRPORT

4.8.1 Evaluation of Pavements
Due to the highly directional prevailing winds at this airport, over 90 percent of all operations are conducted in the easterly direction on runway 8-26. Other runways at the airport have, therefore, been omitted for this B-2707 compatibility study.

Both flexible and rigid pavements are used at this airport. Rigid pavements consist of 12- to 15-in. of concrete laid over varying thicknesses of compacted coral base. Flexible pavements, varying in thickness from 24- to 75.5-in., are constructed of bituminous concrete surface, a crushed coral base, and, where required, a coral subbase. The existing soil conditions are extremely complex and variable, ranging from poor to excellent.

The subbase rating for concrete pavement in the terminal area is equivalent to k = 400, based on a subgrade rating of k = 170 under a 24-in. thick base. The base for concrete pavement on runway 8-26 in Hickam Air Force Base is rated by the Corps of Engineers as k = 300. Minimum subgrade CBR values from limited test data range from 3 in the airfield area to 7 in the north portion of the terminal area. No data are available for most of the terminal area. The entire runway area has been given an FAA classification of F9, based on an E-12 soil.

Flexural stresses induced in the apron area and for pavement at the west end of runway 8-26 are somewhat higher for DC-8-55 loadings than for the B-2707. Costs of improvements, if any, would not be attributable to the B-2707.

Apron and taxiway flexible pavements in the terminal area are 24-in. thick and give good service under DC-8 and other heavy jet traffic. The 24-in. pavement section with the DC-8 loading of 328,000 lb requires a subgrade CBR of 14.5. This value is judged to be more representative of actual subgrade strength than the single low value of 7 noted. For a CBR of 14.5, the required pavement thickness for the B-2707 is 26 in., or 2 in. more than the existing thickness. The apron and taxiways, however, are scheduled for a 3-in. overlay in 1967 - 1968. These pavements, therefore, are considered to be compatible with the B-2707.

Taxiway A, between taxiway D and Hickam Air Force Base (Fig. 4-16) has a minimum pavement thickness of 24 in. In some areas of soft clay or muck, the pavement has been placed on a minimum of 48 in. of compacted select material and 6 in. or more of select backfill. For the DC-8, this 24-in. pavement would require a CBR of 14.5 for the compacted select material. Since this taxiway has performed satisfactorily for the DC-8 and other heavy jet traffic, a strength equal to a CBR of at least 14.5 is considered to exist, as in the adjacent apron area. A 3-in. overlay is scheduled in 1967 - 1968 for the Honolulu sections of taxiway A and runway 8-26. Therefore, taxiway A east of Hickam Air Force Base is considered compatible with the B-2707. The taxiway A section on Hickam Air Force Base is reported to have a minimum thickness of 62 in. It has sustained the loads imposed by the DC-8-55 and other heavy aircraft for several years without adverse effects. The design CBR value of 3 may understate somewhat the true strength of the subgrade. It has been assumed, therefore, that the 62-in. pavement is just adequate for the DC-8-55 at 328,000 lb, with the nearest indicated CBR value of 3.8 used to determine the thickness required for the B-2707.

A CBR value of 3.8 indicates that a 70-1/2-in. pavement thickness would be adequate for B-2707 operations on the Hickam end of taxiway A. An anticipated overlay of not less than 2 in. will be placed at the time the 3-in. overlay is placed on the Honolulu portion of taxiway A. The resulting wearing course will then total 6-in. of asphalt, half of which includes a base equivalence factor of 1.5, making the equivalent total pavement thickness equal to 65-1/2 in. The B-2707 will require 70-1/2 in., or a 5-in. additional overlay. This amount, adjusted for base equivalence, is 3-1/2-in. thick and attributable to the B-2707.

Based on limited boring information, the section of the runway east of Hickam Air Force Base is assumed to have a minimum pavement thickness of 66 in., of which the upper 4 in. is a bituminous wearing surface. The placement in 1967 - 1968 of the planned 3-in. overlay will increase the actural thickness to 69 in. If the base equivalence factor of 1.5 is applied to the existing 4-in. wearing surface, the effective total pavement thickness at the time the B-2707 enters service will be 71 in. For noncritical runway areas, the ability of such a pavement to support the B-2707 would require a CBR of 3.3. The pavement is thus compatible with the B-2707.

In view of the improved methods of placing fill, quality of materials employed, and its traffic history, a minimum CBR of 3.8 has been assumed for the Honolulu section of the runway. The Honolulu segment of runway 8-26 will this be compatible with the B-2707. Similarly, with the planned overlays, the 3,350-ft of runway 8-26 immediately west of the Hickam-Honolulu property line will also be compatible with the B-2707.

4.8.2 Requirements for New Pavements

The geometry of all paving fillets was taken from plans made available by the airport operator and verified from an aerial photograph. Of the 31 fillets and 3 curved taxiways investigated, 3 fillets will require improvement. General assumptions and criteria leading to the standards adopted for the present evaluation may be found in Par. 4.2.3. Fillet modifications, where required to accommodate the B-2707, are minimized by the 200-ft width of runway 8-26 and the 75-ft width of certain connecting taxiways.

No holding aprons are presently utilized or planned. This is due to the unique "no delay" clearance given all jet aircraft from their gate positions.

Figure 4–16 Honolulu International Airport

A two-way taxiway adjacent to the terminal at Honolulu International Airport is presently being used. Operation of the B-2707 on this taxiway in a two-way mode will necessitate widening. A planned master plan study will consider terminal area revisions, including the possible elimination of the two-way taxiing system. Nevertheless, in the absence of detailed planning, the costs that would be incurred by an adequate widening of this taxiway system have been attributed to the B-2707.

4.8.3 Evaluation of Structures
Runway 8-26 and its two parallel taxiways cross Manuwai Canal, which is on the property line of Hickam Field. The canal is carried in a six-cell, reinforced-concrete box culvert beneath taxiway A. The cells of the box are 10-ft wide by 9-ft deep inside, and the interior walls are structurally hinged top and bottom. It is possible, therefore, to analyze the top and bottom slabs of the culvert independently, since structural continuity is provided only through the exterior walls. The top slab has ample strength and, on the basis that wall loads are carried by narrow strips of the bottom slab, the bottom slab is also adequate for the B-2707.

Beneath runway 8-26 the canal is carried in part by three-box and two-box reinforced-concrete culverts, and in part by 6-ft-diameter reinforced-concrete pipe culverts. About 15 years ago, the box and pipe culverts were strengthened. These were checked for the loads imposed by the B-2707 and found to be adequate.

Available data indicates that all other pipes and conduits beneath the airfield pavements are within the range of acceptable conditions stated in Par. 4.2.3.

4.8.4 Terminal Area Considerations
The terminal area at Honolulu consists of a central terminal building and elevated concourses, the segments of which form a Y with the central terminal at the top. To the west of the main building and paralleling the east-west runway is a series of buildings that accommodate international arrivals. From the center of the terminal area to the east, another series of buildings curve gradually to the north. Perimeter gate positions located on the airport side of these buildings are not assigned to specific airlines but are assigned by the tower on arrival. All 19 of these gate positions are virtually identical in plan layout, fuel hydrant positioning, and guidance striping. When the B-2707 enters service at Honolulu, it is probable that only one method of parking will be used.

Both canted and parallel parking positions are shown on Fig. 4-17. Both modes are compatible with existing gate positions, terminal area maneuvering, and servicing. Both methods require the use of two existing gate positions. The B-2707 gate positions will remain compatible with subsonic airplane requirements. If a slight articulation of the B-2707's nose is required to clear the low blast fences such a maneuver will be acceptable.

The terminal apron must be widened to permit ramp vehicle traffic to clear parked airplanes. The cost of this modification is included in the estimate.

Honolulu International Airport presently uses mobile ramps. The Department of Transportation does not contemplate the installation of second-level loading devices in the future.

Each of the 19 gates at Honolulu International is fueled by an underground system. All positions are served by a pair of hydrant fueling pits located along a line perpendicular to the terminal face and spaced 80-ft apart. Some of the pits have additional fuel lines which carry a duty-free fuel for certain overseas operations. The B-2707 may require some modification to the existing system, and the estimated per gate cost is shown in Par 4.8.5.

Figure 4-17. Honolulu Terminal Area

4.8.5 Estimated Costs

a. Lump Sum Items

Taxiway A overlay at $2.50 per sq yd	$104,000
Modification of one fillet on Hickam AFB:	
Full-strength pavement at $16 per sq yd	24,000
Shoulder pavement	3,000
Revisions to lights	2,000
Modification of 2 fillets on H.I.A.	
Full-strength pavement at $7 per sq yd	10,000
Revisions to lights	2,000
Expansion of terminal taxiway and apron	
Full-strength pavement at $7 per sq yd	150,000
Shoulder pavement	19,000
Revision to lights	10,000
Total Estimated Costs	$324,000

b. Unit Cost per Gate Position

Fuel system modifications	$17,000

4.9 HOUSTON INTERCONTINENTAL AIRPORT
Now under construction on a 7,200-acre plot north of Houston is the first major U.S. airport planned for a previously underdeveloped tract since Dulles International Airport was constructed in the late 1950's. The planners and designers of Houston Intercontinental Airport (Fig. 4-18) began their work at a time when the general compatibility requirements of the supersonic transport were beginning to become apparent. As a result, the specific compatibility requirements of the B-2707 would make necessary only minor modifications at this new airport.

4.9.1 Evaluation of Pavements
Pavements of Houston Intercontinental Airport are of Portland cement concrete. A relatively high-strength subsoil was produced by removing the sandy topsoil, compacting the subsoil and shaping it to drain, replacing and compacting the sandy topsoil to a high density. Upon the compacted subgrade were placed soil-cement base courses, 9- to 12-in. thick. The combined modulus of subgrade reaction achieved by these means varies from k = 265 to k = 450. The airport's designers selected slab thicknesses of 11, 12, and 14 in. to accommodate the various conditions of support and eventual use. The B-2707 will impose stresses well within the concrete allowable stress. The B-2707 is compatible with the airports pavements.

4.9.2 Requirements for New Pavements
Included in the investigation were 97 fillets, of which 29 would require improvement. Fifty percent of the cost of fillet improvement is necessitated by "rare" B-2707 usage. General assumptions and criteria leading to the standards adopted for the present evaluation may be found in Par. 4.2.3. Planned extensions of runways 8L-26R and 14-32 were assumed to be completed prior to introduction of the B-2707.

The 325-ft-wide holding aprons that will serve the thresholds on runway 8-26, the ILS runway, are more than ample for holding and passing the B-2707. By the criteria stated in Par. 4.2.3, the 250-ft-wide aprons of runway 14-32 are just short of being adequate. The costs of widening have been estimated and allocated to the B-2707.

4.9.3 Evaluation of Structures
Six airplane overpass structures will eventually be required in the terminal area. They will be designed for the heaviest airplane that can be reasonably anticipated at this time and will be adequate for the B-2707.

A system of culverts will drain the taxiway infield areas. Having been designed for 100,000-lb equivalent single wheel loads, these structures have the strength required to resist live loads imposed by the B-2707. Other conduits are of adequate design.

4.9.4 Terminal Area Considerations
The terminal at Houston Intercontinental Airport is based on the concept of unit terminals for passenger processing and multiple satellites for boarding and deplaning (Fig. 4-19). Two unit terminals are scheduled for construction during the first phase of development. Each terminal will ultimately be served by four satellite flight stations, each designed to provide gate positions for five subsonic jet airplanes. The unit terminals are square in plan, and the concourses connecting them to the satellite flight stations are extensions of their diagonals. Thus, separate aprons are provided on two opposing sides of the unit terminals. These aprons are 740-ft wide and permit two-way taxiing operations with all gate positions occupied by current jet airplanes. The gate positions for each airplane are designed for nose-in loading; however, each airline may, at its own option, make the rearrangements necessary

Figure 4–18. Houston Intercontinental Airport

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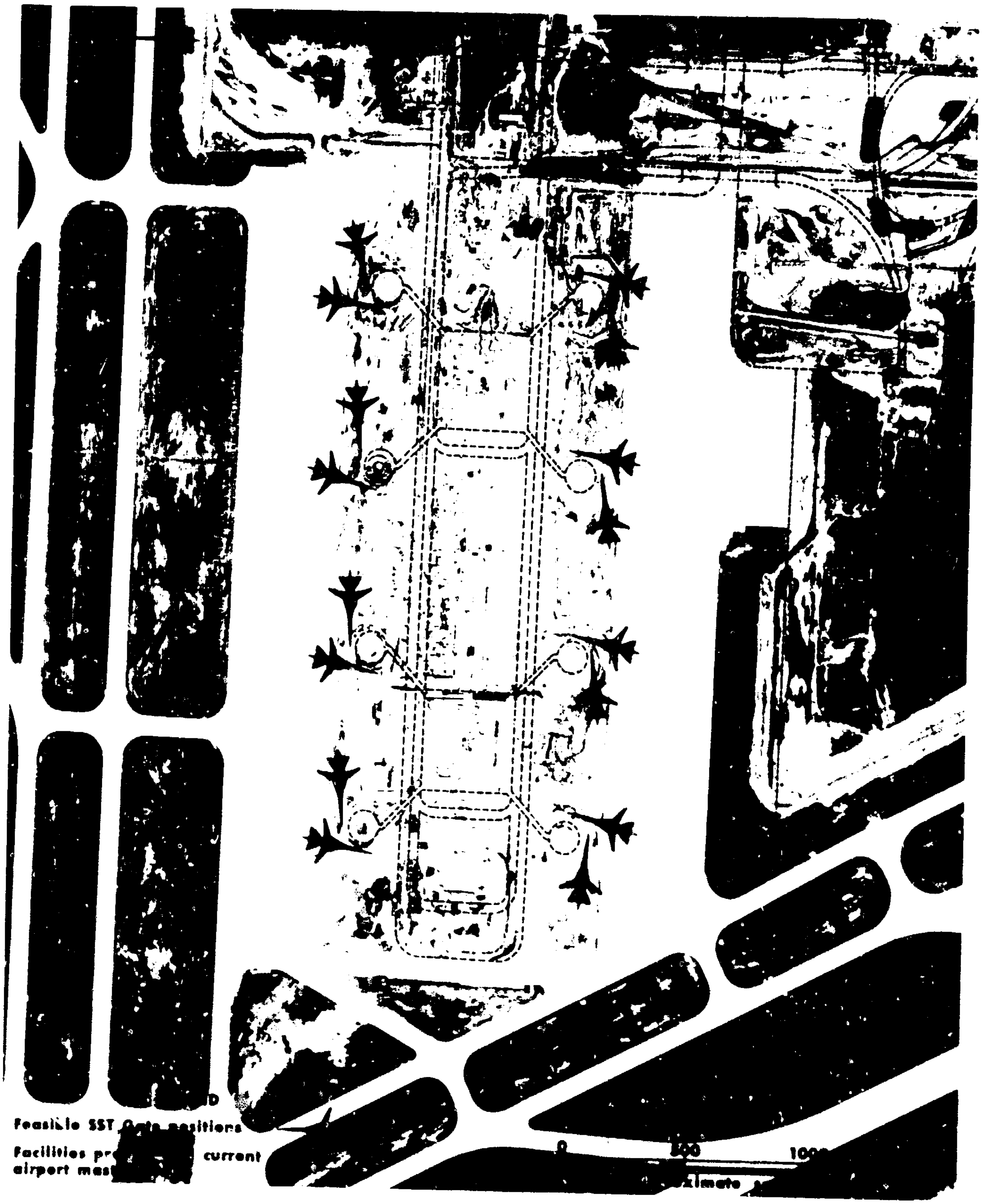

Figure 4–19. Houston Terminal Area

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to permit canted or parallel parking. Fig. 4-19 shows docking positions for simultaneous usage by two B-2707's at each of the eight flight pavilions. Of the two positions, one would intrude upon the inner taxi lane and impose a somewhat increased expenditure for passenger loading bridges.

The need for modifications to passenger loading devices will depend upon equipment selected by the individual airlines. It is assumed that the selection of any passenger-loading equipment will be made at the proper time in consideration of the B-2707 requirements.

An underground hydrant fueling system has been designed consisting of one 12-in. and four 16-in. supply mains feeding two 10-in. lines looping around each of the satellite flight stations. The system will be pressure-controlled from the tank farm and will be capable of supplying 20,000 gpm at 100 psi. Hydrant locations at leased gate positions have been determined by each airline on the basis of their current aircraft equipment and their intended mode of parking. Those positions to be used for B-2707 docking will require new hydrants. The costs will be attributed to the B-2707.

4.9.5 Estimated Costs

a. Lump Sum Items	
Modifications to 29 fillets:	
Full-strength pavement at $15 per sq yd	$189,000
Revisions to lights and signs	38,000
Widening of 2 holding aprons:	
Full-strength pavement at $15 per sq yd	$ 17,000
Revisions to lights	2,000
Total Estimated Costs	$246,000
b. Unit Costs Per Gate Position:	
Passenger Loading devices	$ ---
Fuel system modifications	$7,000

4.10 LOS ANGELES INTERNATIONAL AIRPORT

4.10.1 Evaluation of Pavements

Both rigid and flexible pavements have been constructed at Los Angeles International Airport. In the area of the airport west of Sepulveda Boulevard (Fig. 4-20), the natural subgrade soil is a loose sand. When excavated and recompacted in layers, it provides a good subgrade for runway and taxiway construction. East of Sepulveda Boulevard, the subgrade is a clay soil.

Portland cement concrete pavements in thicknesses of 9, 10, 12, and 15 in. are presently in use. The 12- and 15-in. concrete pavements are compatible with the B-2707. The 10-in. runway 7L-25R pavement performs satisfactorily under current jet traffic and is also compatible with the B-2707. The 9-in. pavement occurs only at the runway 25L holding apron, scheduled to be abandoned soon.

A number of flexible taxiway and runway pavements west of Sepulveda Boulevard are 19-in. thick. These have been a source of trouble. On the basis of its experience with them, the Department of Airports has concluded that the CBR method of pavement design is more applicable at Los Angeles. In general, the 19-in. flexible pavements are scheduled to be replaced with 15-in. concrete pavements (which are compatible with the B-2707) in the near future. Such pavements include portions of runways 7R-25L, 7L-25R, and taxiways J-38 and H-36.

All of the terminal apron taxiways are 37-in. thick and are compatible with the B-2707. Runway 6-24 and sections of runway 7R-25L - all west of Sepulveda Boulevard - are flexible pavements 22- to 25-in. thick. Since the B-2707 requires a flexible pavement thickness in critical and noncritical areas 2 in. greater than the DC-8, the proportional cost of that thickness of a strengthening overlay has been charged to the B-2707. East of Sepulveda Boulevard, taxiway 2-J, which has a theoretical deficiency of several inches, has been holding up very well under frequent heavy loadings. This is attributed to its adobe subgrade. It is not anticipated that taxiway 2-J will require any improvement to support the B-2707.

4.10.2 Requirements for New Pavements

Each fillet that would be traversed by the B-2707 was investigated. A total of 159 fillets and two curved taxiways were studied, of which 27 fillets and one curved taxiway will require improvement. The geometry of the fillets was taken from plans made available by the airport operator and verified from an aerial photograph. The general assumptions and criteria leading to the standards

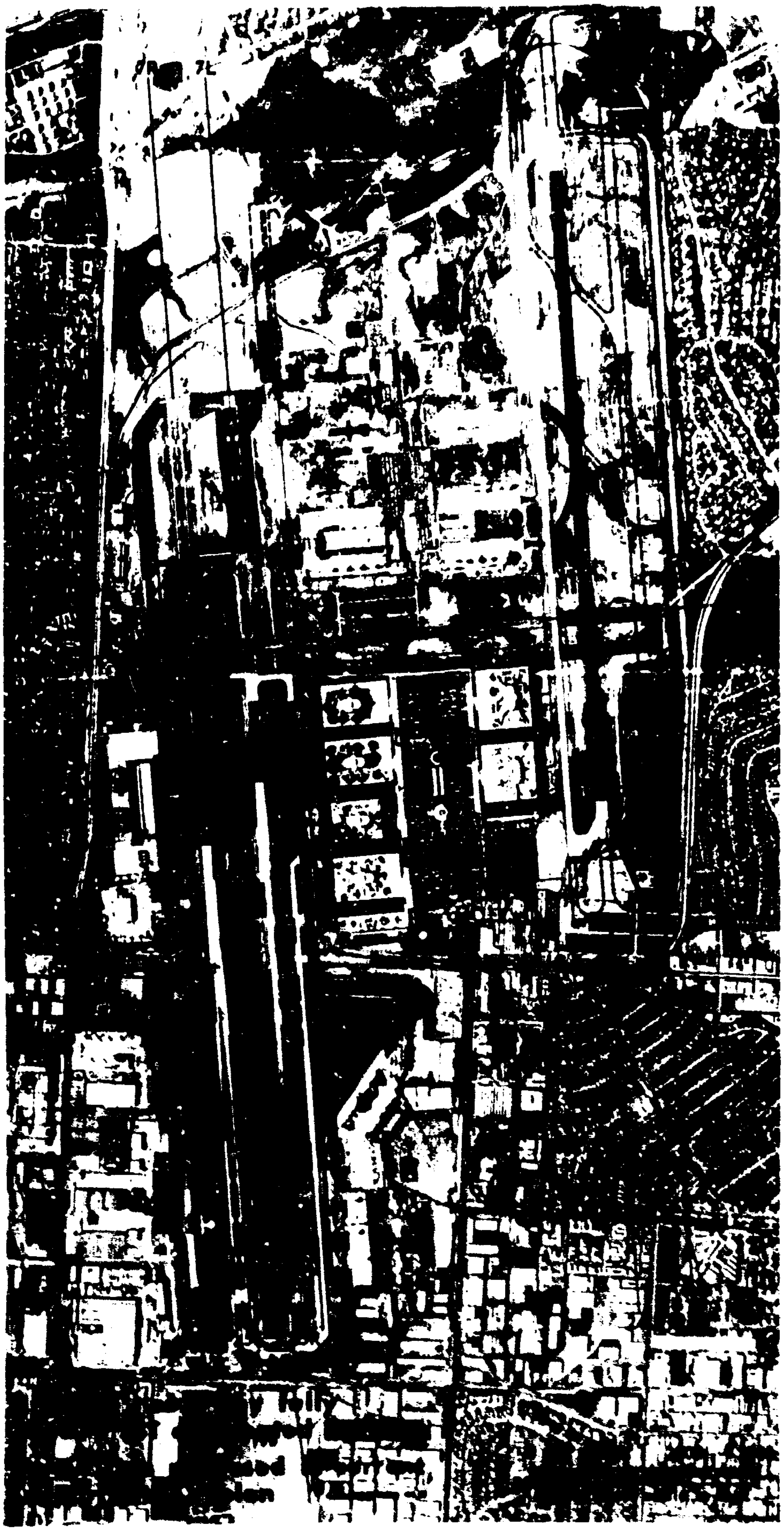

Figure 4-20. Los Angeles International Airport
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adopted for the present evaluation may be found in Par. 4.2.3 of this report. The specific assumptions made for the investigation of the fillets at Los Angeles are as follows: (1) Runway 16-34, which is very seldom used, will either be relocated or abandoned; (2) taxiway K between the threshold of runway 7L and taxiway 53-J will be widened from its present 60-ft width to 75 ft; (3) taxiway K between a point opposite satellite 5 and the United Air Lines maintenance apron at the eastern end of the airport is used only rarely; i.e., when taxiway J is closed; (4) taxiway F is used only by the military and by the nonscheduled airlines.

Most operations at Los Angeles are to the west. However, there may be 5 to 10 days a year when the direction and velocity of the wind dictate that landings and takeoffs be made to the east. Because of the density of traffic at the airport, it is essential that ground traffic not be unnecessarily delayed at any time. Investigation of taxiway geometry has been made on the basis of east and west operations.

Holding aprons have been constructed at the threshold of existing runway 24 (future runway 24L) and between the thresholds of runways 25L and 25R. Both would require widening to meet the criteria stated in Par. 4.2.3 for the holding and bypass maneuvering of the B-2707. A 60-ft widening would be appropriate for the full length of the apron serving the runway 25 threshold. A 50-ft widening and a variable lengthening would provide B-2707 compatibility with the runway 24 apron. This would require the relocation of a blast fence and an extension of approximately 100 ft of a 58-in. by 36-in. corrugated metal pipe arch. Both improvements would require the resetting of existing edge lights and new shoulders. The apron at the runway 24 threshold would require the installation of several new edge lights.

In order to maintain the terminal area maneuvering standards recommended in Par. 4.2.3 for the B-2707, a major modification of the existing taxiway and apron systems would be required. This includes full-strength pavement, shoulder pavement, and revisions to lights and signs required to widen the peripheral taxiway in the terminal area north of satellites 2 and 3 and south of satellites 4 through 7.

4.10.3 Evaluation of Structures

Los Angeles International Airport is transected by Sepulveda Boulevard, which runs in an approximately north-south direction immediately east of the terminal area complex (Fig. 4-20). The relationship of highway and airport facilities is such that the parallel east-west runways and taxiways south of the terminal area must be carried over the highway. The vehicular subway constructed for this purpose is a two-span, reinforced-concrete rigid frame. This subway must be modified to accommodate new large-capacity subsonic transports which will precede the B-2707 into service. After these modifications are made, the structure will be compatible with the B-2707.

The perimeter drain at Los Angeles is an 8-ft, 6-in. by 10-ft reinforced-concrete box culvert that passes in various places below aprons, taxiways, and runways. This structure was checked for the live-load condition imposed by the B-2707. The calculated maximum stresses at critical sections were found to be within their respective allowable values.

The ticketing buildings on the perimeter of the circulation roadway are connected to their respective satellites by passenger and baggage channels running beneath the airplane parking apron. Certain of the satellites are similarly interconnected by passenger channels. It is unlikely that the B-2707 would ever be maneuvered between the ticketing buildings and satellites, or onto the aprons between satellites. For that reason, no investigation was made of the adequacy of the existing channel construction.

All pipes and conduits beneath airfield pavements are within the range of acceptable conditions stated in Par. 4.2.3.

4.10.4 Terminal Area Considerations

The Los Angeles International Airport terminal area employs the unit terminal and satellite concept. Ticketing buildings arranged along opposite sides of the parking and central services areas are connected each to its own satellite by channels beneath the apron. The entire perimeter of a satellite is available for positioning aircraft. The proximity of the satellites to each other and to their respective ticketing buildings prohibits parking of the B-2707 at interior gate positions. The eight exterior positions indicated on Fig. 4-21 would require major improvements to the existing

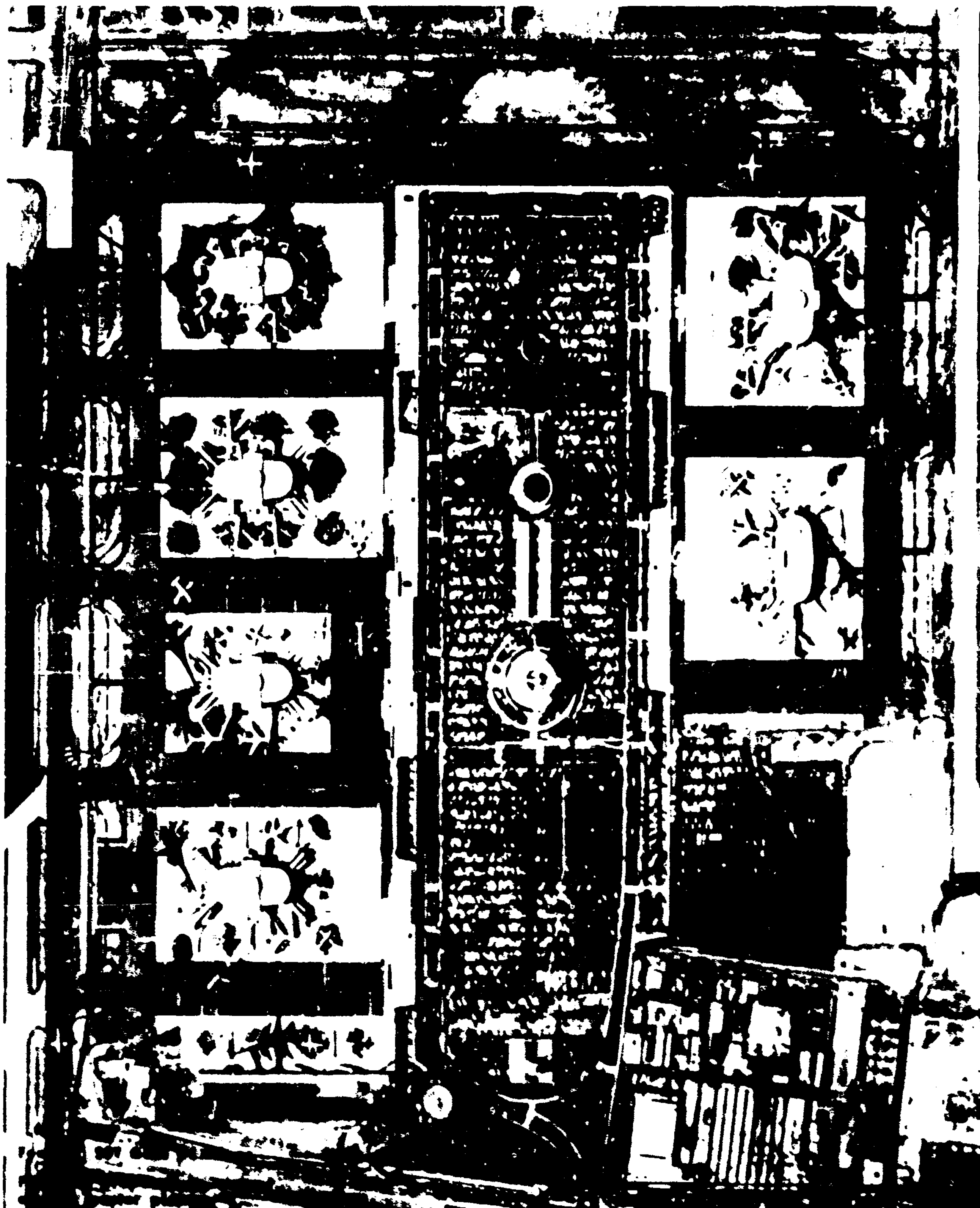

Figure 4-21. Los Angeles Terminal Area

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taxiway and apron system. Terminal area occupancy that could be attained without major modification of the buildings is also indicated on Fig. 4-21. One position each has been provided at satellites 2, 4, 5, 6, 7, and 8, and two at satellite 3. Parking positions are all canted, with the exception of one parallel at satellite 3. The particular arrangements selected have been investigated for feasibility of convenient maneuvering, effects on the availability of adjacent gate positions, and adaptability to existing gate arrangements and loading procedures.

The airlines at Los Angeles employ both second-level loading devices and mobile ramps. The second-level devices included fixed and swinging nose-loaders and swinging-telescoping bridges. At satellite No. 2, since no loaders now exist, the new equipment which will be required to serve the B-2707 is not considered chargeable. For the parallel parking position shown at satellite No. 3, the two existing swinging telescopic-type loaders can be used to meet the forward and second doors of the B-2707, although minor modifications will be required for the second door position. For the canted position shown, the one existing loader of the same type can be utilized to serve the forward door. A new loader will be needed for the second door at this position. New loaders will be required at satellite No. 4 to serve the position indicated. It is not considered feasible to modify the existing equipment which is designed primarily to accommodate nose-in loading of subsonic aircraft. Loaders currently exist at satellite No. 5, the new equipment which will be required is chargeable to the B-2707. The existing swinging-telescoping loader at satellite No. 6 can serve the forward door A new loader of a similar design will be needed to serve the second door. New loaders will be required at satellite No. 7 to serve the canted parking position indicated. Since loaders exist at all other positions, the new ones required for the B-2707 have been charged to the B-2707. At satellite No. 8, the two existing swinging-telescoping loaders can be modified to accommodate the position shown on Fig. 4-21.

All of the satellite terminals are served by the underground fueling system. Each individual satellite was examined to determine general fueling requirements for the B-2707.

At satellite No. 2, the existing lateral, provided with new 4-in. hose connections, will provide adequate service. At satellite No. 3, two new hydrants and associated lateral pipes will be required. The loop system serving satellites No. 4, 5, 6, 7, and 8 are adequate for the B-2707 positions. Two new hydrants and associated laterals will be required at each satellite.

4.10.5 Estimated Costs

a. Lump Sum Items	
Overlay pavement at $1.20 per sq yd	$260,000
Modifications to 27 fillets and one curved taxiway:	
Full-strength pavement at $15 per sq yd	115,000
Shoulder pavement	24,000
Revisions to lights and signs	29,000
Widening of runway 24L holding apron:	
Full-strength pavement at $15 per sq yd	32,000
Shoulder pavement	6,000
Revisions to lights	3,000
Relocation of blast fences and obstruction lights	3,000
Extension of 58 in. by 36 in. CMP arch	4,000
Widening of runway 25L-25R holding apron:	
Full-strength pavement at $15 per sq yd	41,000
Shoulder pavement	5,000
Revisions to lights	1,000
Widening of terminal aprons:	
Full-strength pavement at $15 per sq yd	693,000
Shoulder pavement	84,000
Revisions to lights and signs	36,000
Total Best estimate	$1,336,000
Fire and rescue Equipment	150,000
Total High estimate	1,486,000
b. Unit Cost Per Gate Position	
Passenger loading devices	80,000
Fuel System Modifications	20,000

4.11 MIAMI INTERNATIONAL AIRPORT

4.11.1 Evaluation of Pavements

Both rigid and flexible pavements have been constructed at Miami International Airport. In some areas, rigid pavements have received bituminous overlays.

The largest areas of rigid pavement at Miami are the airplane parking areas adjacent to the piers extending from the terminal building. All of them are 10-in. slabs placed on a 12-in. compacted base of blended sand and rock with a measured minimum CBR of 60. Almost all of the remaining concrete pavement in the terminal area is 8-in. thick, with a stabilized sand base varying in thickness from 0 to 8 in. Almost all of this pavement has been overlaid with 3 in. of asphaltic concrete, and the remaining section is scheduled for a 3-3/4-in. overlay. Short sections of runways 9R-27L and 12-30 are also paved with 8-in. concrete supported by stabilized sand bases of various depths up to 8 in. They have not been overlaid. There are several small areas paved with 6-in. concrete on stabilized sand bases. All rigid pavements that might be subjected to heavy B-2707 loadings have been inspected. The majority of the terminal apron pavements are in good condition. Those areas which need improvement are either scheduled for overlay or it may be assumed they will be improved prior to the introduction of the B-2707. Many of the thinner pavements without overlays are seriously overstressed by the fully-loaded DC-8-55 and would be subjected to even higher stresses by the B-2707 at maximum gross weight. However, should it become necessary to overlay any pavements not presently programmed for improvement, the thickness requirements of non-rigid overlays adequate for DC-8-55 loadings would exceed, by fractions of an inch, those of the B-2707. Therefore, although the B-2707 would create the greater stress on existing rigid pavements, the costs of strengthening overlays would be attributable entirely to the DC-8-55.

All of Miami's flexible pavements are now 12 or more inches thick. For the recommended subgrade classification of Fa, both the DC-8 and the B-2707 require 11-1/2 in. of pavement in critical pavement areas. It is concluded, therefore, that all of Miami's flexible pavements are compatible with the B-2707.

4.11.2 Requirements for New Pavements

Of the 164 fillets investigated, using both plans and aerial photographs, 25 would require improvement. The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in Par. 4.2.3 of this report. The specific assumptions made for the investigation of the fillets at Miami are as follows:

a. If runway 12-30 were to remain at its current length, several of the exit taxiways nearest to the runway 12 landing threshold would receive little or no use by the B-2707. As Fig. 4-22 indicates, however, the runway is to be extended. As a result, the exit taxiways in question will be used routinely by the B-2707. The assumption has been made that the planned extension will be completed prior to the introduction of the B-2707.

b. The Dade County Port Authority has a continuing program of fillet improvement, and it is possible that some fillets will be improved prior to the introduction of the B-2707. However, the present investigation takes into account only those fillet improvements that are firmly planned for 1967.

Runway 9L-27R, the primary usage runway at Miami International, is 200-ft wide. As a result, no fillet modifications are required for the B-2707 adjacent to this runway.

There are holding aprons at each end of each of the four runways at Miami. All but two of the eight aprons meet the criteria stated in Par. 4.2.3. The two inadequate aprons are located at the ends of runway 17-35. This runway is rarely used by the airlines, and the aprons at their thresholds would not be used by the B-2707. Accordingly, it is assumed that these aprons will not be improved specifically for the B-2707.

In addition to the holding aprons at the runway thresholds, there are supplementary aprons located approximately 1300 ft from the thresholds of runway 9R and 9L. It is unlikely that such aprons would ever be utilized by the B-2707 and no improvements are anticipated.

4.11.3 Evaluation of Structures

Two box culverts are installed at Miami International Airport, but the B-2707 is unlikely to cross either of them so they were not investigated.

Owing to the high level of ground water at Miami, pipe and conduit have been installed with shallow cover under both rigid and flexible pavements. In recognition of the effects on such installations of live loads transmitted through shallow cover, due care has been taken in their selection and installation. From the data made available, it is judged that all pipes and conduits beneath airfield pavements are within the range of acceptable conditions stated in Par. 4.2.3.

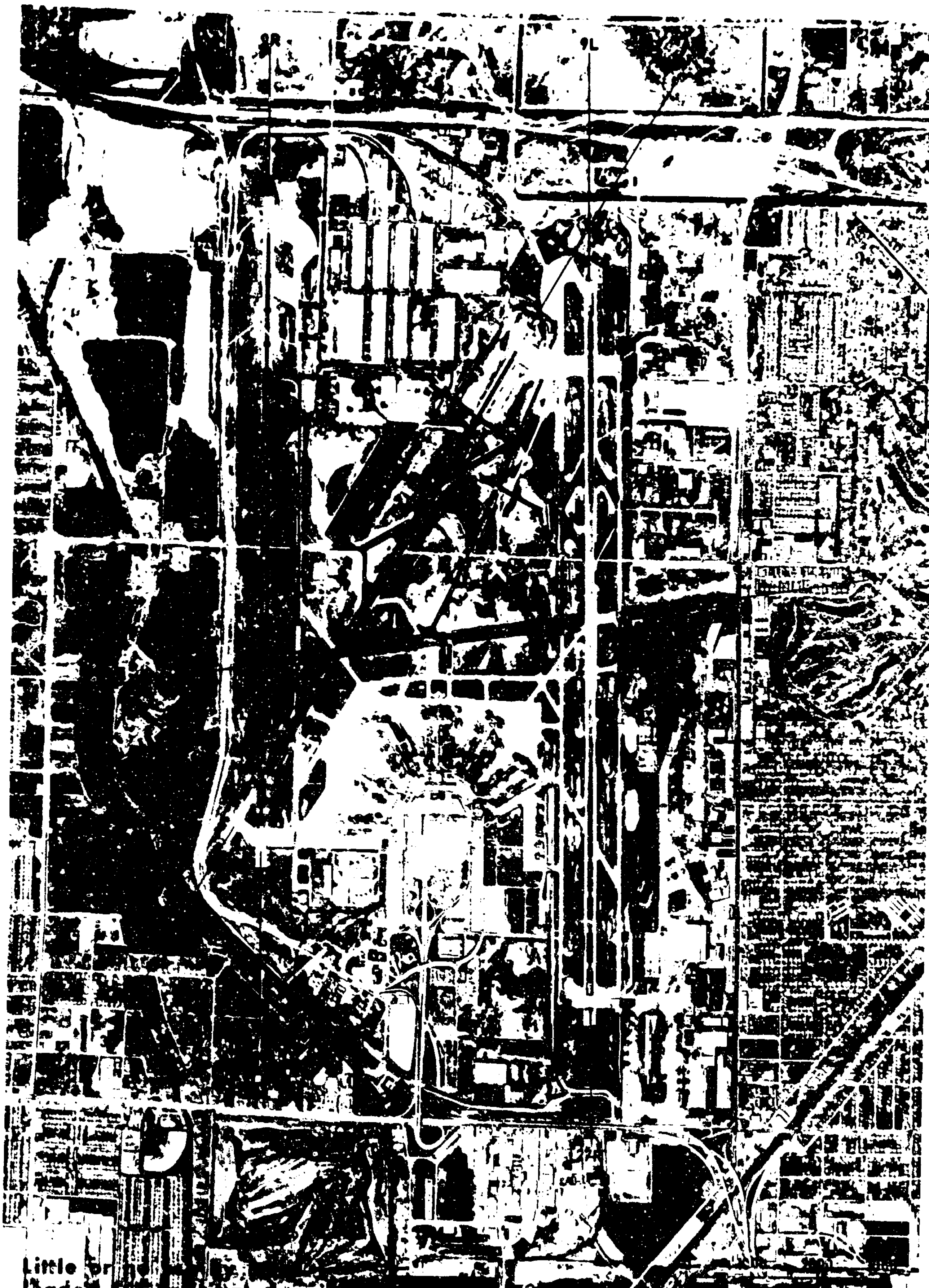

Figure 4-22. Miami International Airport

4.11.4 Terminal Area Considerations

The terminal area at Miami comprises a long, central terminal and service building, the several segments of which form a U, from which six concourses, or passenger loading piers, extend at diverging angles of 30 deg. Concourse 4, the International Building, is in the form of a T; the others are linear, some with and some without angular turns. The resulting apron areas lend themselves conveniently to the arrangement of airplanes of various space requirements, with the smaller airplanes assuming positions near the base of the pier and the larger airplanes occupying the gates farther out. Sixteen parking positions have been indicated at the six Miami finger piers. At five of the six terminal building concourses, some use is made of second-level passenger loading devices. Only those installed at the outermost gate positions are of concern to the present investigation. The scheduled modifications to concourse 6 include the installation of bridges similar to those on concourse 5; however, their locations have not been fixed as of this writing.

At the B-2707 gate positions shown on Fig. 4-23 for concourses 1, 3, and 4, the length of the nose of the B-2707 would require either new or relocated bi-rail loaders, plus new swinging-telescoping loaders or swing loaders in conjunction with short fixed bridges. An alternative considered by the airport operator consists of simple building extensions on which the rail-mounted loaders could be rehung. The latter solution may be preferable from the operator's standpoint, since the loaders would be retained and additional needed hold-room space would be provided.

At the three B-2707 gate positions shown for concourse 5, the B-2707 can be paralled-parked close enough to the face of the terminal to be reached by the existing telescoping bridges. Some modification to the two bridges used for second-door loading will be needed to reach the height of the second-door sill of the B-2707.

For the purpose of this report, new bi-rail loaders and swinging-telescoping type loaders have been estimated, where needed. The existing swing-type loaders at concourse 5 can be modified to serve five of the door positions indicated. One new bi-rail type loader will be required for the end position shown. All positions at other concourses will require new or relocated loaders. Loaders for the two positions indicated at concourse 2 are not considered chargeable to the B-2707, since none now exist in these areas. These modifications will be compatible with subsonic airplanes.

Underground hydrant fueling facilities have been installed at concourses 3, 4, 5, and 6. The system at concourse 4 is electrically operated; those at the other concourses are actuated by pressure-sensing devices. An under-apron transfer system has been installed but never placed in service at concourse 1. It is designed to deliver fuel received from tenders at the outer edge of the parking apron to hydrants located under the airplane fueling receptacles.

A new underground system, which will probably be considered for concourses 1 and 2 to service the four B-2707 positions shown there, is not chargeable to the B-2707.

The existing 12-in. and 14-in. loops serving the remaining piers are sufficient to provide the required capacity for the B-2707. A system of new laterals and two new hydrants at each B-2707 position will be required and is shown in the cost estimate.

4.11.5 Estimated Costs

a. Lump Sum Items	
Improvements to 25 fillets:	
Full-strength pavement at $6 per sq yd	$ 67,000
Shoulder pavement	14,000
Revision to lights and signs	19,000
Total Estimated Costs	$100,000
b. Estimated Unit Costs per Gate Position	
Passenger loading devices	$110,000
Fuel system modification	7,000

4.12 JOHN F. KENNEDY INTERNATIONAL AIRPORT, NEW YORK

4.12.1 Evaluation of Pavements

Both rigid and flexible pavements have been constructed at John F. Kennedy International Airport. Most pavements have been placed on dredged sand. Engineers of the Port of New York Authority recommended the use of a California Bearing Ratio (CBR) of 15 and a modulus of subgrade reaction (k) of 300.

Figure 4-23. Miami Terminal Area

V4-B2707-1

All runways, some taxiways and sections of taxiways, and the greater area of apron pavements are Portland cement concrete. The runway pavements, which have been designed for a maximum allowable flexural stress of 430 psi, are 12-in. thick. All other rigid pavements are 13-in. thick. Their maximum allowable flexural stress is 365 psi. On both the 12-in. and 13-in. thick pavements, the DC-8-55 at 328,000 lb induces higher stresses than does the B-2707 at 675,000 lb. At 98 percent and 93 percent, respectively, of the maximum allowable stress, neither vehicle overstresses the 12-in. pavements. On the 13-in. pavements, however, the DC-8 induces a slight overstress (4 percent) while the B-2707 induces a stress 3 percent less than the allowable. On the basis of these findings, it is concluded that the rigid pavements at Kennedy are adequate for both airplanes.

Most taxiway pavements at Kennedy are of flexible construction. According to the Port Authority's engineers and planners, all such pavements either are 22-in. thick now or will be overlaid to that thickness prior to the inauguration of B-2707 services. The typical section comprises a 4-in. surface course and a 12-in. base. Use of Corps of Engineers' design method with the recommended CBR value of 15 results in paving thickness equal to 23.5-in. for the DC-8-55 and 25-in. for the B-2707. The thickness deficiency of pavements subjected to B-2707 loadings is 3-in. The deficiency for DC-8 loadings is 1-1/2 in., however, the full amount of the costs estimated for a 3-in. thick asphaltic concrete overlay have been allocated to the B-2707. Figure 4-24 shows the areas eliminated from consideration of the additional 3-in. overlay because of infrequent use by fully loaded B-2707's.

There are sections of 18-in. thick flexible pavement on the aprons serving the International Arrivals Building and the unit terminal building occupied by Northeast, Northwest, and Braniff Airlines. They comprise a 4-in. surface, an 8-in. base, and a 6-in. subbase. In theory, they are deficient by 5-1/2 in. (23.5 percent) for the DC-8 and by 7 in. (28 percent) for the B-2707. From a comparison of the theoretical thickness deficiencies expressed as percentages, it is judged that the two terminal apron pavements in question would probably be compatible with the B-2707. Therefore, no costs for their strengthening are attributed to the B-2707 in the "best" estimate given in Par. 4.12.5. In the event that pavement distress traceable to B-2707 operations occurs, it would be reasonable to attribute to such operations the full cost of a pavement improvement. Anticipating that such an improvement would be made by inlaying concrete to match adjacent pavement, a "high" estimate of the full estimated costs of removing existing flexible pavements and replacing them with a 13-in. rigid slab is given in Par. 4.12.5.

4.12.2 Requirements for New Pavements

A total of 247 fillets and all curved taxiways were carefully investigated and it was determined that 109 fillets require improvement. The geometry of the fillets was taken from plans made available by the airport operator and verified from an aerial photograph. The cost estimate for these improvements are included in Par. 4.12.5. The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in Par. 4.2.3.

The following have been determined to be the minimum desired holding capabilities of the runway threshold aprons:

- Hold two B-2707's at runways 31L, 22R, and 13R
- Hold one B-2707 at runways 4L, 31R, and 13L
- No holding requirements at runways 4R, 7, and 25
- Hold the same number of airplanes as the apron was originally designed to hold

a. Runway 31L

The holding apron for runway 31L is a trapezoidal-shaped pavement located at the end of a decommissioned runway which is now designated taxiway Z. It has sufficient area to hold three large subsonic jets. However, to enable this apron to hold two B-2707's and one large subsonic jet and meet the Port Authority's requirements, it will be necessary to enlarge the pavement. All costs for such improvements, including blast fence requirements, have been attributed to the B-2707.

b. Runway 22R

The apron here is presently adequate for four current subsonic jets. It is adequate in width for holding B-2707's and is backed by a blast fence erected to protect a taxiway. It has been assumed that the pavement area would be increased to permit the holding of two large sub-

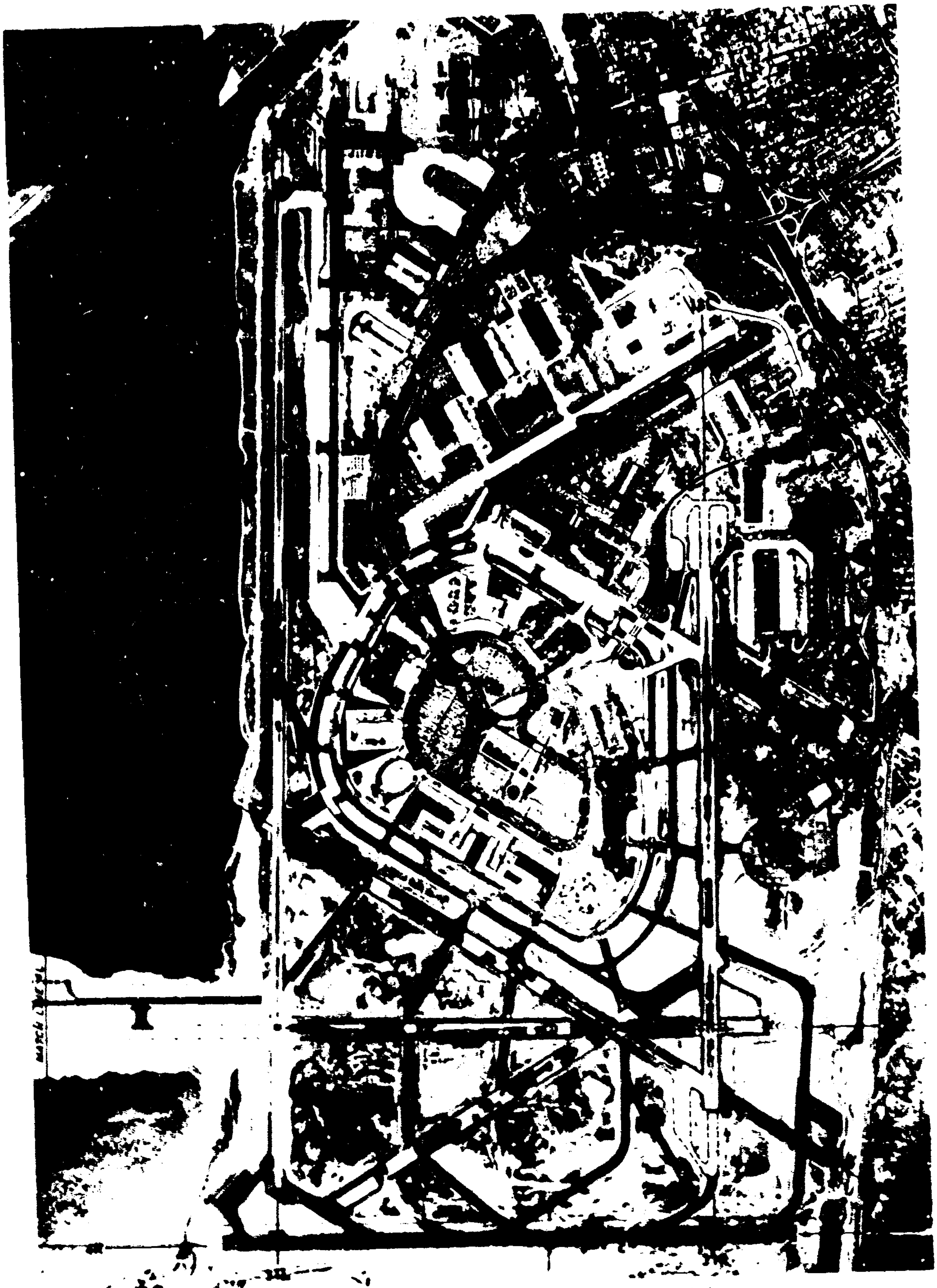

Figure 4-24. John F. Kennedy International Airport, New York

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sonic jets and two B-2707's by an expansion of the northwest end. The cost of this expansion, including blast fence extension, has been included in the estimate.

c. Runway 13R

There is an L-shaped holding apron adjacent to the takeoff threshold of runway 13. The long leg of the apron is parallel and close to a taxiway serving airline maintenance facilities, and a blast fence now separates the two. The entire apron will presently accommodate five large subsonic airplanes. It will also have the capacity to hold two B-2707's and three subsonic jets. The Port Authority engineers have questioned the effects that the efflux from a holding B-2707 might have on the high tail surfaces of airplanes on the adjacent taxiway. Studies indicate that, as the B-2707 swings from the apron toward the hold bar, the distance from its exhaust nozzles to the adjacent taxiway is about 200 ft. There would be an effect, but it is not regarded as severe. However, since it is impractical to raise the blast fence, a holding apron extension to the west far enough to accommodate two B-2707's turned in the takeoff direction has been included in the cost estimate.

d. Runway 4L

The holding apron can presently accommodate three subsonic jets. It would also be adequate for one B-2707 and two subsonic airplanes, although the spacing would be somewhat tight. In order to meet the criteria, and maintain operational flexibility, this apron will require expansion. The cost of expansion, including embankment fill in Jamaica Bay, pavement, shoulders, and revision to lights, is included in Par. 4.12.5.

e. Runway 31R

The apron proposed for the current extension of the runway 31R threshold would be inadequate in width for the B-2707. Its length is adequate for one B-2707 and two subsonic jets. The cost of widening the apron has been estimated and attributed to the B-2707.

f. Runway 13L

The threshold apron proposed for the extension of runway 13L is not wide enough for an existing large subsonic jet to pass a B-2707 that is holding. There appears to be no practical solution to the problem involved in expanding the apron's depth. The rear edge of the proposed apron will be separated from 150th Street by a 14-ft-high steel blast fence; consequently, the apron cannot be widened toward 150th Street. Relocating the street itself to the southwest would not be warranted. The feasibility of holding the B-2707 on the existing apron serving 13L has been investigated. However, this apron is inadequate for the same reason cited for the proposed apron. We have assumed, therefore, that B-2707's required to hold will do so in the large area formed by the intersection of taxiways A and X, and no charges will be allocated to the B-2707 for apron expansion at the runway 13L threshold.

4.12.3 Evaluation of Structures

There are four taxiway bridges on the airport. The older pair, designed in 1946, carries the dual circumferential taxiways over Van Wyck Expressway, the primary access road. The second pair, designed in 1962, carries the same taxiways over the 150th Street entrance roadways. Plans of the newer pair of bridges have been reviewed, and it has been determined that they are fully capable of supporting the B-2707 at maximum gross ramp weight.

The Van Wyck Expressway bridges are two-span, continuous structures with center-to-center-of-bearing distances of about 65 ft in each span. This structure has been investigated and it has been found that both the B-2707 and the DC-8-55 produce serious overstresses in the steel beams. Improvements of the bridges are warranted now if they are subjected to frequent loadings from the largest of today's jet aircraft at or near their maximum gross weights. Therefore, costs of structural modifications to the Van Wyck Expressway bridges have not been attributed to the B-2707.

Seven large reinforced-concrete box culverts were investigated. Using conservative analytical assumptions, it was found that the culverts would have overstresses of less than 25 percent due to the loads imposed by the B-2707. As a result of the analyses and in view of the present condition, it has been assumed none of these culverts would be replaced due to B-2707 operations.

From available data, it is judged that all pipes and conduits beneath airfield pavement are within the range of acceptable conditions stated in Par. 4.2.3.

4.12.4 Terminal Area Considerations

The terminal area at Kennedy now comprises an International Arrivals Building and six domestic unit terminals. Two other unit terminals, one for a non-U. S. airline, are presently projected for completion within a few years. The seven existing terminals fall into three basic classifications:

a. The central building with two or more concourses extending outward into the airplane apron (Eastern, United-Delta, American, and the International Arrivals Building)

b. The self-contained terminal at which the aircraft docks by nosing in (PAA and Braniff-Northeast-Northwest)

c. The central terminal with concourses and satellite buildings (TWA)

Studies were made of each terminal, and it was determined that the B-2707 could be accommodated as shown on Figs. 4-25 and 4-26, where it is feasible for the airplane to be maneuvered and docked by conventional techniques.

International Arrivals Building (Fig. 4-25). Only BOAC has installed passenger loading bridges. The BOAC gate serviced by these loaders is not a suggested B-2707 gate. Therefore, no bridge cost adjustment has been charged to the B-2707.

Trans World Air Lines Terminal (Fig. 4-25) Existing passenger loading is accomplished by swinging telescoping loaders. The forward-entry door is compatible with the vertical articulation of the loaders; as a result no costs are attributable to the B-2707.

Pan American Airlines Terminal (Fig. 4-25) Existing loaders are of the swing type with an open platform guarded by handrails. They reach only to the forward door of current airplanes. The platforms would have to be altered to meet the front door of the B-2707. An enclosed telescoping loader at each B-2707 position would be required to provide adequate weather protection and to reach the doors while holding both points simultaneously.

American Airlines Terminal (Fig. 4-26) The east concourse could be equipped to serve the B-2707 with two bi-rail loaders. The end position of the west concourse presently has one bi-rail nose-loader, which could be supplemented by an additional bi-rail loader on a swinging-telescoping loader, from an extended holdroom. For the canted position at the west concourse, it has been estimated that a new swinging-telescoping loader would be provided for the second door and a swinging fixed-length loader for the forward door.

United - Delta Airlines Terminal (Fig. 4-26) The south concourse has two B-2707's shown with the westerly airplane serviced by existing swinging-telescoping loaders. The forward-entry door is compatible with the vertical articulation of the existing passenger loaders. The second position at the south concourse will require two new loaders, not chargeable to the B-2707 because the concourse does not at present have loading devices.

Eastern Airlines Terminal (Fig. 4-26) This terminal does not at present have any loading devices. Possible future loading devices for B-2707 operation could only presume second-story additions to the existing single-level north and south concourses. Therefore, passenger loading devices are not considered for this facility at this time.

Braniff-Northeast-Northwest Terminal (Fig. 4-26) At the terminal's northwest corner, an assumed B-2707 position, two loaders are available for use. One loader, of the swing type with fixed cab, would require a rotating cab. The second loader is a swinging-telescoping bridge, which would require vertical adjustment to reach the second-door sill. The east side of this terminal does not have loading devices. Two new loaders are suggested for this position.

Underground fueling systems are presently installed at the International Arrivals Building and at the permanent terminals of the various airlines. Fueling at temporary terminals is still carried on by fuel tenders. At the International Arrivals Building, airlines can choose between the fuel of four different suppliers, resulting in eight hydrants for each present airplane position.

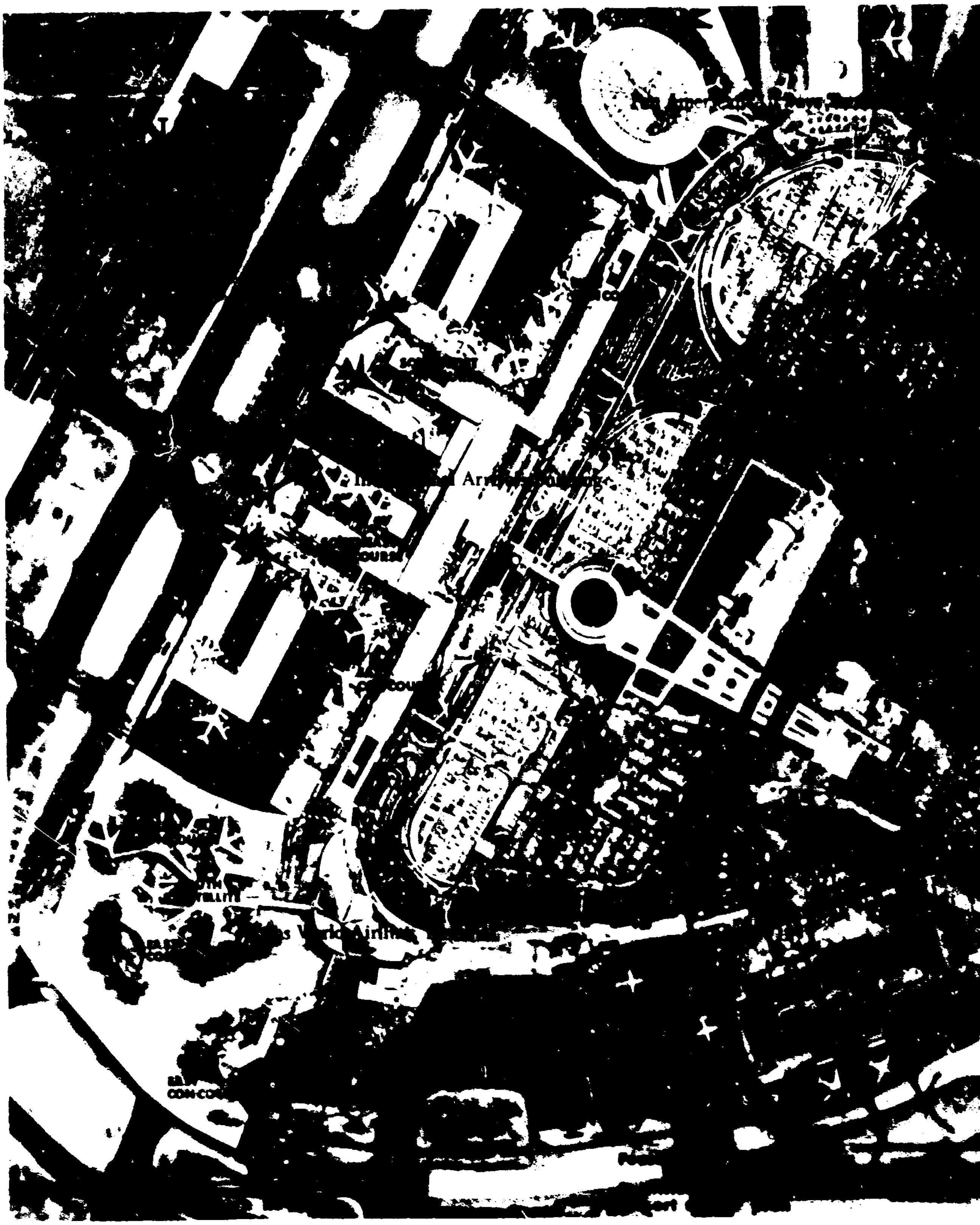

Figure 4–25. John F. Kennedy Terminal Area for Pan American, International Arrival Bldg, Trans World

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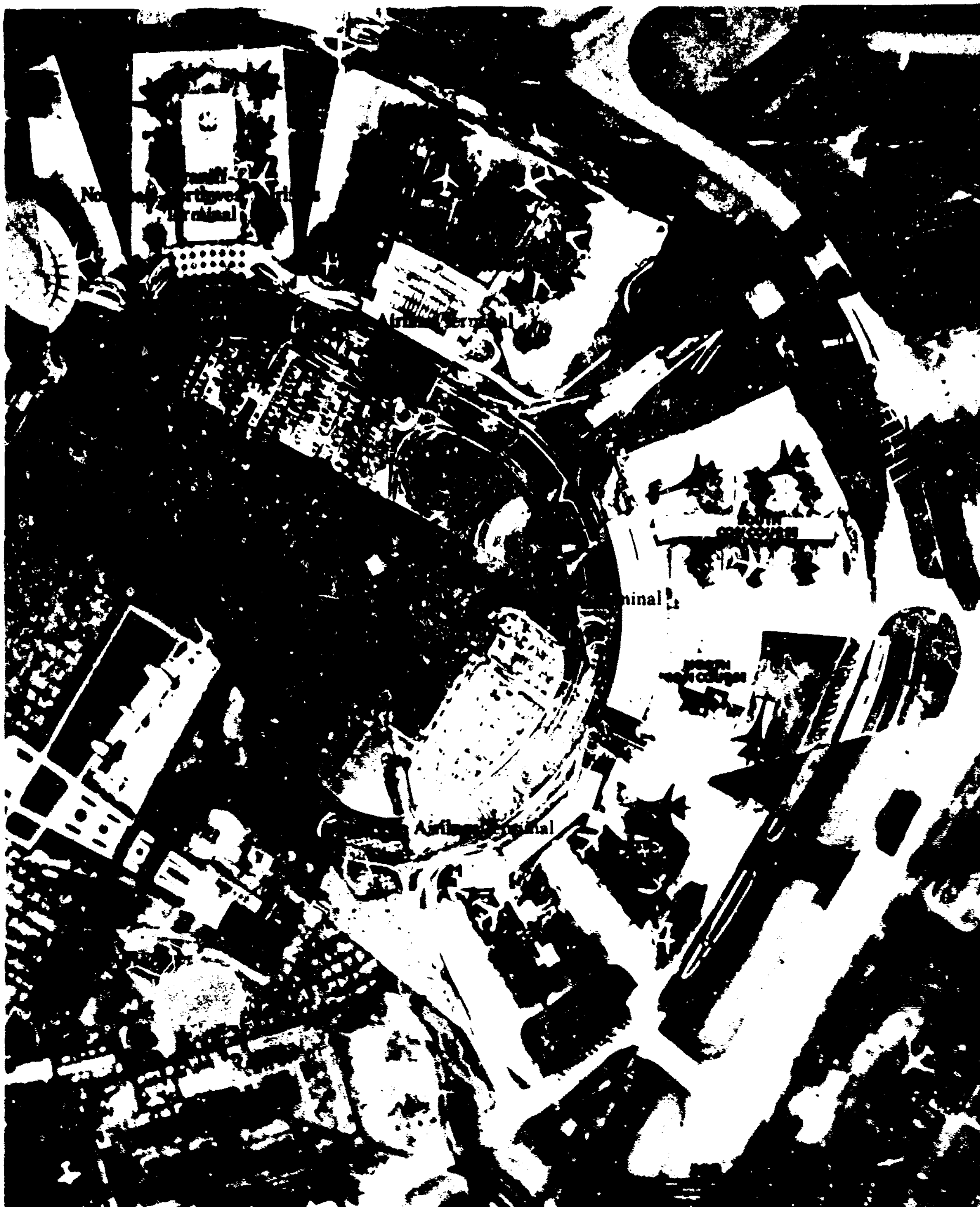

Figure 4-26. John F. Kennedy Terminal Area for Braniff, Northeast-Northwest, Eastern, United-Delta, American

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The Port of New York Authority has erected eight blast fences at Kennedy in locations where airplanes, either holding or taking off, direct their engine blasts at other facilities. In general, present blast fences are adequate for B-2707 operations. However, the holding apron serving runway 22R, which is required to be expanded at its northwest end, is separated from an adjacent taxiway by a metal blast fence 10-ft high. If runways 22R and 22L are used during peak hours for takeoffs or if runway 25 will be retained and used in conjunction with 22R for takeoffs, airplanes taxiing behind the apron of runway 22R would cross the axis of the B-2707 engine efflux. The fence should be extended at its present height as required by the apron extension needed for holding the B-2707. The costs of such an extension have been estimated and included in Par. 4.12.5.

4.12.5 Estimated Costs

A "best" estimate and a "high" estimate have been submitted. The "best" estimate reflects those costs that are most properly attributable to the B-2707. The "high" estimate represents the maximum potential cost that might be incurred by the B-2707.

a. Lump Sum Items

Taxiway overlaps at $2.20 per sq yd	$ 990,000
Modifications to 109 fillets:	
Full-strength pavement at $15 per sq yd	540,000
Shoulder pavement	130,000
Revisions to lights and signs	160,000
Expansion of 5 holding aprons:	
Full-strength pavement at $15 per sq yd	484,000
Shoulder pavement	34,000
Revision to lights	9,000
Embankment	80,000
Extend blast fence - runway 22R, 31L	63,000
Subtotal	$2,490,000

	High Estimate	Best Estimate
Terminal apron inlays at $17 per sq yd	$1,700,000	$ 0
Total Estimated Costs	$4,190,000	$2,490,000

b. Unit Costs Per Gate Position

Passenger loading devices	$ 57,000
Fuel system modifications	20,000

4.13 PHILADELPHIA INTERNATIONAL AIRPORT

4.13.1 Evaluation of Pavements

Both rigid and flexible pavements have been constructed at Philadelphia International Airport. Some sections of rigid pavement have received bituminous overlays. Most of the airport pavements have been or are being constructed on sand fills that have been placed hydraulically and allowed to settle over a tidal marsh.

The terminal apron and certain of the existing taxiways are 12-in. thick portland cement concrete. Engineers of the Division of Aviation recommend a value for the modulus of reaction of the subgrade of k = 250. They also recommend the use of a maximum allowable flexural stress in the slabs of 295 psi. The choice of the latter value is based upon their observations of the performance of the rigid pavements that have required overlays. Analyses of the stresses that would be induced by the DC-8-55 and the B-2707 on the airport's rigid pavements show that each airplane would cause serious stress conditions; however, since the B-2707 would create the lesser overstress, no costs have been allocated to it for rigid pavement improvements.

The thickness or composition of the airport's original pavements is not known with certainty. However, data are available on improvements made during the last 15 years. In 1951, the existing east-west runway was extended approximately 2300-ft westward on a subgrade composed of 6 ft of selected backfill classified as E-2 soil. The new pavement is 15-in. thick. In 1959, a further extension of about 2200 ft was added, which consisted of a 14-1/2-in.-thick pavement structure on 4-ft of material classified as E-2 soil with good drainage characteristics. A subgrade classification of Fa was used in the design. At the same time, a minimum of 1-1/2 in. of bituminous overlay was added to the previous construction of runway 9-27. The most recent design for a flexible pavement at Philadelphia is that for the taxiway parallel to runway 17-35. For an F2 subgrade classification, the pavement section specified is 18-in. thick. Since the engineers judge that the old construction of unknown thickness is performing as well as the newer construction, they have recommended that the present investigation of

Philadelphia's flexible pavements be based on the known FAA subgrade classification of F2 and a CBR of 20. Use of the methods employed by the FAA and the Corps of Engineers for the design of flexible pavements in critical areas yields the following required total thicknesses:

	FAA Method	Corps of Engineers' Method
DC-8-55	18 in.	18.5 in.
B-2707	16.5 in.	20 in.

By the Corps of Engineers' method, the 1959 extension of runway 9-27 would be deficient by 5-1/2 in. However, the results of standard tests performed on the selected backfill placed there, as well as the requirements of the specifications under which it was placed, indicate that at least this much of the backfill may be considered as subbase. The existing flexible pavements will be compatible with the B-2707 and that planned future pavements will be at least equal to those now in use.

4.13.2 Requirements for New Pavements
The requirements for new pavements have been reviewed on the assumption that all the proposed work included in the Airport Master Plan shown on Fig. 4-27 will be finished by the time the B-2707 is operating. It should be noted that this complete implementation of the master plan will revise and eliminate significant sections of current pavements, particularly the terminal area peripheral taxiway. Runway 9R-27L, its parallel taxiway, and a bypass taxiway system are currently under construction and the contract drawings for the work have been reviewed.

In accordance with the general procedure outlined in Par. 4.2.3, careful review of the existing plans and areas under construction indicates that half of the fillets will be negotiated during normal operations and the other half will only be turned under unusual conditions. Runway-runway intersections were not investigated, since the B-2707 can smoothly negotiate any such turn. After analyzing each standard intersection and the nonstandard intersections by use of a model, it was determined that, out of 68 fillets and 2 curved taxiways, 16 fillet modifications and modifications to the two curved taxiways would be required. Costs are summarized in Par. 4.13.5.

According to the Airport Master Plan, there will be a total of six holding aprons serving the six runway thresholds. The aprons at the ends of runways 9L, 9R, 27L, and 35 are completed or under construction. Of these four, only the holding apron at the runway 35 threshold is not of adequate dimensions to satisfy the requirement that a current subsonic jet be able to bypass a B-2707 holding with wings in the full-open position. A suitable widening for this apron has been planned and estimated. The remaining aprons at the end of runways 9R and 17 are in the planning stage. From the Airport Master Plan, the runway 9R apron will be adequate for the B-2707, but runway 17 apron is not large enough for the B-2707 to pass currently operating commercial airplane. Final planning for this particular apron may dictate an expansion beyond that shown on the current master plan. For this reason, no estimated cost for widening the holding apron at the runway 17 takeoff threshold has been included. The only holding apron expansion attributable to the B-2707 is that required at the end of runway 35. The cost estimate is included in Par. 4.13.5.

4.13.3 Evaluation of Structures
There are a number of drainage structures so located in the airfield pavements at Philadelphia that they are subjected directly to airplane gear loads. Each of the different types was investigated to determine its adequacy for supporting the maximum loads imposed by the B-2707. The investigations included grates, frames, supporting beams, and footings. Moderate overstressing was found in the cast-iron grate frames and in the hooked bars in the toes of footings. These overstresses were not sufficient to warrant replacement of the existing structures.

Available data indicate that all pipes and conduits beneath airfield pavements are within range of conditions stated in Par. 4.2.3.

4.13.4 Terminal Area Considerations
The existing terminal area at Philadelphia International Airport employs the central terminal and finger pier concept. The central terminal building is a long, rectangular structure from which three concourses extend to the south at slightly divergent angles. At the present time, a major redevelopment of the terminal complex is anticipated. The current terminal area concept envisions two unit terminals with six satellite clusters providing 66 gates. Figure 4-28 shows this scheme superimposed upon an aerial photograph of the existing terminals. Studies were

Figure 4-27. Philadelphia International Airport

V4-B2707-1

Figure 4-28. Philadelphia Terminal Area

V4-B2707-1

made of B-2707 docking and maneuvering at the planned future facilities. Eighteen B-2707 positions are available adjacent to the flight pavilions.

All loading and unloading of passengers at Philadelphia are by means of push-up ramps. Second-level loading will be employed when the terminal area is improved. It was assumed that the loading devices eventually selected will be compatible with the B-2707 at planned positions. No charges have been allocated to the B-2707 for passenger loading system modifications.

Aircraft fueling has been and is now performed with tank trucks. If the truck supply system is retained, it will be adequate for fueling the B-2707. Should a hydrant system be installed, it is assumed that the initial installation would be made compatible with the needs of the B-2707.

4.13.5 Estimated Cost

Lump Sum Items	
Widening of 16 fillets and 2 curved taxiways:	
Full-strength pavement at $15 per sq yd	$102,000
Revisions to lights and signs	24,000
Widening of Runway 35 holding apron:	
Full-strength pavement at $15 per sq yd	39,000
Revisions to lights	1,000
Total Estimated Costs	$166,000

4.14 PORTLAND INTERNATIONAL AIRPORT

4.14.1 Evaluation of Pavements

Pavement areas at this airport are shown on Fig. 4-29. All pavements are flexible, constructed partly on dredged sand, but principally on existing flood plain deposits, which are clay and silt soils.

The Port of Portland's Aviation Department has recommended the following ratings for existing subgrades:

- Area 1 - Runway 10L-28R, adjacent taxiways and terminal apron: CBR = 10.6
- Area 2 - Runway 10R-28L and adjacent taxiways: CBR = 15.

Area 1 pavements are 37-in. thick, while in Area 2, the thickness in the critical area is 26-in. and 23 in. in the noncritical area.

For all existing subgrades, these pavements exceed the thickness required by the B-2707. Lending support to this conclusion is the belief that the B-2707 will be operated infrequently at maximum gross weight from this airport.

4.14.2 Requirements for New Pavements

The geometry of all paving fillets was taken from plans made available by the airport operator and verified from an aerial photograph. Included in the investigation were 41 fillets, 3 of which require improvement, and 3 curved taxiways. General assumptions and criteria leading to the standards adopted for the present evaluation may be found in Par. 4.2.3. Fillet modifications, where required to accommodate the B-2707, are minimized by the 200-ft width of runway 10R-28L.

The holding aprons located near the thresholds of runways 10L and 28L conform to criteria in Par. 4.2.3.

4.14.3 Evaluation of Structures

All pipes and conduits beneath airfield pavements are within the range of acceptable values stated in Par. 4.2.3.

4.14.4 Terminal Area Considerations

The terminal area at Portland International Airport is patterned on the concept of the central terminal with finger piers. Two such piers, providing a total of 24 gate positions, extend divergently from Portland's central terminal building. The clear distance between them at their ends is approximately 800 ft, which provides ample maneuvering space. The angle of convergence of the piers is such that the B-2707 can maneuver well into the apron area. However, neither of the two interior gate positions adjacent to the terminal building can be utilized by the B-2707 because of blast considerations. An extension of the north pier has been proposed, but construction is not yet planned. The additional four gates contemplated for this extension will accommodate the B-2707.

The airport management has indicated that two B-2707 gate positions will probably be adequate at first. To attain a maximum degree of flexibility in maneuvering, the B-2707 gates on the outside of the two existing piers would be utilized. Adequate space is available to accommodate additional positions when they are needed. Each gate

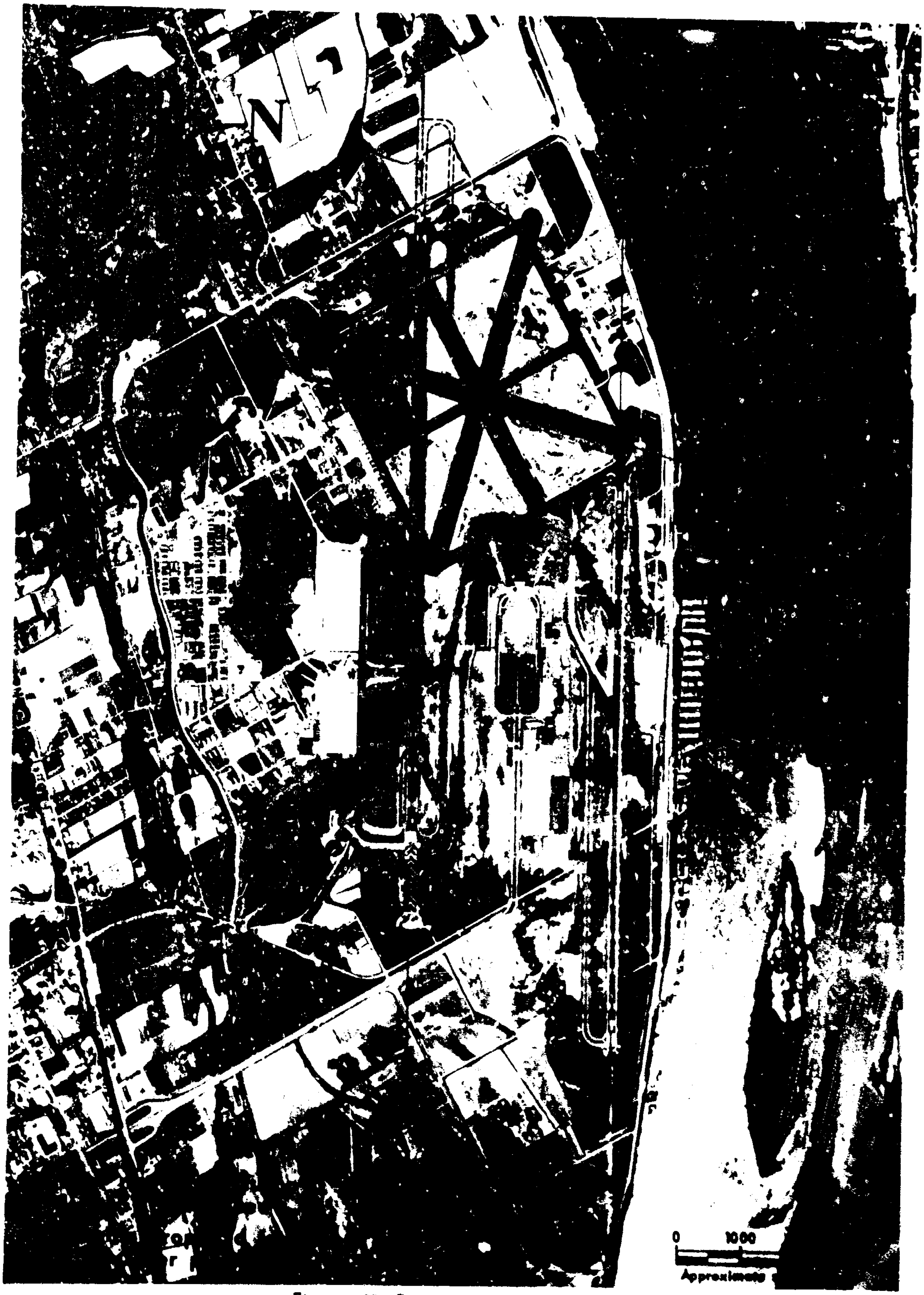

Figure 4–29. Portland International Airport

V4-B2707-1

Figure 4-30. Portland Terminal Area

V4-B2707-1

position shown has been individually investigated for maneuvering convenience, adaptability to existing gate arrangements, and passenger-loading arrangements.

Nine gate positions, located near the base of the piers, currently have passenger-loading bridges. The remaining 15 gates utilize mobile ramps to load and unload passengers. The loading devices are of three different kinds, including:

- Rail-mounted nose-loaders having about 6 ft of horizontal travel (six installed)
- Swinging, non-extensible, nose-loaders (two installed)
- Swinging, non-extensible, loaders with rotating cabs (one installed).

Where rail-mounted nose-loaders are now installed on the outer perimeter, it would be necessary either to provide a new loader of the necessary length or to extend a hold room outward some distance and affix the bi-rail nose-loader to the extension. Initially, only the forward-door loading will be required at Portland International. At the two B-2707 parking positions indicated on Fig. 4-30, there are non-swinging, fixed-length loaders with retractable cabs. The estimated cost reflects a requirement for two new loaders.

Airplane fueling is now performed by mobile tenders, which are operationally flexible and readily available. Any hydrant fueling system will be made compatible with demands of the supersonic transport.

4.14.5 Estimated Costs

a. Lump Sum Items

Improvements to 3 fillets:

Full-strength pavement at $8 per sq yd	$17,000
Shoulder pavements	3,000
Revisions to lights and signs	4,000
Total Estimated Costs	$24,000

b. Unit Costs Per Gate Position

Passenger loading devices	$40,000

4.15 SAN FRANCISCO INTERNATIONAL AIRPORT

4.15.1 Evaluation of Pavements

At San Francisco International, concrete pavement is generally used for the critical end-sections of runways, for holding aprons, for certain taxiways, and for hardstands on certain terminal aprons. All other pavement, including noncritical sections of runways and the greater proportion of terminal aprons, is flexible. In areas of flexible pavement distress, it is now the practice to make improvements with concrete inlays. On runways, the central 60 ft is inlaid; on taxiways, the central 45 ft. Elsewhere, flexible pavements considered substandard are being resurfaced. The airport is constructed on a reclaimed portion of San Francisco Bay (Fig. 4-31) by dry-fill placement of sandy soil from a nearby borrow area. Since the bay here was once a tidal marsh on organic silt up to 60 ft in depth, both differential and overall settlements of the airport have occurred in the past and are expected to continue. The Public Utilities Commission, which operates the airport, reports that the airport soil classification is F2 and that a subgrade CBR value of 15 is appropriate for the B-2707 compatibility evaluation. (The Corps of Engineers' method of flexible pavement design is preferred by the commission.) It has also given a k-value of 400 for the top of the cement-treated base used extensively for both rigid and flexible pavements. For the rigid pavement, all of which is 13-in. thick, 325 psi is the allowable flexural working stress.

For the DC-8-55, a flexural stress of 356 psi is induced in the concrete pavement. For the B-2707, this stress is 333 psi. In the unlikely event that such minor overstresses as these would require rigid pavement improvements, the costs would be properly attributable to heavily loaded subsonic jet aircraft rather than to the B-2707. Sections of rigid pavement have been constructed in the terminal apron area. At concourses G, F, and FF, there are wide strips of concrete at the aircraft parking positions. At the other concourses, small concrete pads have been inlaid. The latter would in some cases need to be extended if used as parking positions for the B-2707.

All flexible pavements that will be used by the B-2707 are 18-in. thick except for the new aprons at concourses G, F, and FF, which are 20-in. thick. The cement-treated base is considered to be a high quality base (compressive strength = 750 psi). Its thickness is 10 in. beneath the 18-in.

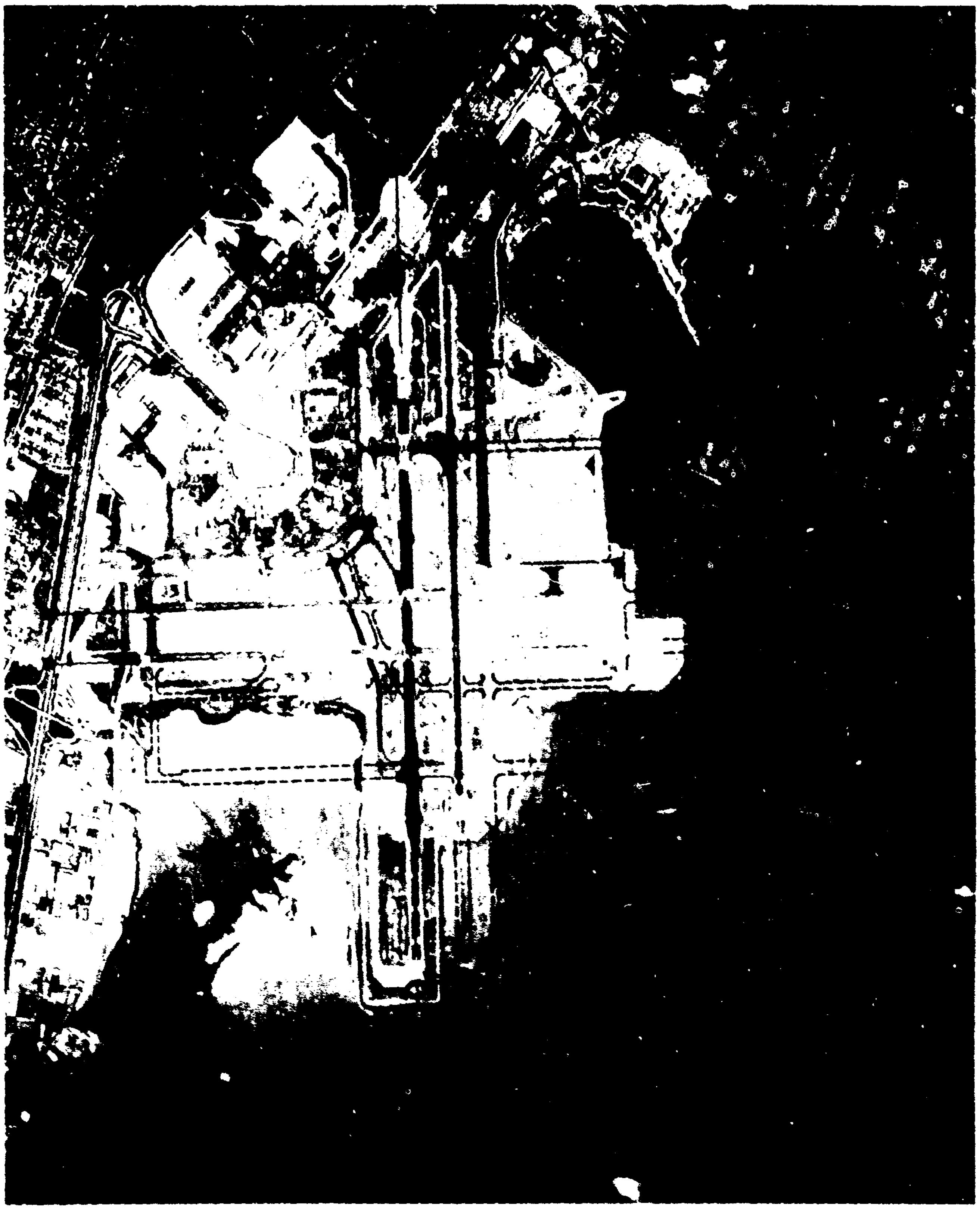

Figure 4–31. San Francisco International Airport

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pavements and 12 in. beneath the 20-in. pavements. Each section comprises, in addition, 4 in. of untreated base and 4 in. of asphaltic-concrete surfacing. In assuming equivalency factors for the cement-treated bases and for 1 in. of the 4-in.-thick surface, guidance has been provided by the consultant to the Public Utilities Commission and by findings of a recent Government research report. An equivalency factor of 1.34 has been used for the cement-treated base (CTB). For both airplanes, the factor of 1.4 recommended by the Commission's consultant for the lowest inch of asphaltic-concrete surface has been used. The equivalent total pavement thicknesses so derived are as follows:

Actual Thickness	Equivalent Thickness
18-in. pavements	21.8 in.
20-in. pavements	24.5 in.

Engineers of the Public Utilities Commission have obtained values ranging from CBR 15 to CBR 80 from field measurements of subgrade strengths. The conclusion was reached that a CBR value of 20 might be more representative of the minimum prevailing subgrade strength than the lowest recorded value of 15. In at least one instance, the Commission, in an application for Federal aid, has indicated a subgrade strength of not less than CBR 20 for a particular area of the airport. The Commission has suggested that CBR 15, rather than CBR 20, be adopted to provide a factor of safety for anticipated growth versions of the B-2707. While this position is understandable, it is not in accordance with the guidelines given by the FAA for the compatibility study and its adoption for the investigation of one airport would represent a departure from the procedure used for all others in the study.

The thickness requirements obtained by the use of both values in the CBR equation are shown in the following tabulation:

	Critical		Noncritical	
	DC-8-55	B-2707	DC-8-55	B-2707
CBR = 15	23.5	25	21	22.5
CBR = 20	18.5	20	16.5	18

The B-2707, the critical airplane, is considered fully compatible with the noncritical sections of 18-in. pavement and with the 20-in. apron pavements. The use of CBR 20 for the subgrade indicates an ample reserve of pavement thickness, while the use of the conservative CBR 15 indicates negligible deficiencies in thickness; i.e., 0.7 and 0.5 in., respectively.

The critical sections of the 18-in. pavements are more than adequate if CBR 20 is accepted. For CBR 15, on the other hand, there would be deficiencies of 3-1/4 in. for the B-2707 and 1-3/4 in. for the DC-8-55. (The equivalent thickness of the pavement, 21.8 in., actually corresponds, for the B-2707, to a CBR value of 18.)

For the B-2707 at 675,000 lb, it is estimated that no costs would be incurred for the strengthening of pavements.

It is recognized that some pavement areas may experience little or no settlement, and that, at least in some areas, a CBR value of 15 may be more nearly correct than that of CRB 20. Under these conditions, certain pavement overlay costs could be estimated as a possible expense, all or part of which might be incurred as a result of B-2707 operations. The "high" estimate, therefore, provides for an overlay of an average thickness of 2-1/2 in. over the areas of critical 18-in. flexible apron and taxiway pavements.

4.15.2 Requirements for New Pavements

The airport operator is planning and making improvements to contend with the increased size of airplanes under development; it may be expected that fillet improvements will be made in the future. Nevertheless, the cost estimates given (Par. 4.15.5) have been based upon the conservative assumption that existing fillet radii will only be improved as required by the introduction of the B-2707. A total of 138 fillets and 10 curved taxiways was investigated, of which 20 fillets and 2 of the curved taxiways will require improvements in accordance with the criteria in Par. 4.2.3. The costs for improvements to the pavements have been estimated and the results summarized in Par. 4.15.5.

The holding aprons at the primary takeoff thresholds of runways 28L and 28R conform to the criteria of Par. 4.2.3.

Supplementary aprons are located west of the 28L and 28R thresholds. It is doubtful that these aprons will be used by supersonic transports. Several of the holding aprons meet the depth requirements of Par. 4.2.3. Utilization of these runway thresholds by significant numbers of departing B-2707's is considered unlikely. The holding aprons at the threshold of runways 1R and

19R are shallow for holding the B-2707. The possibility of expansion is limited by two major drainage canals by the Bayshore Freeway and by San Francisco Bay. Since there appears to be no practical solution for expansion, the conclusion is that this apron will not be enlarged. Modifications to pavement fillets at the holding aprons serving runways 10L and 28R are necessary to meet the maneuvering standards specified for normal operation of the B-2707. Other than the cost of these modifications, which have been included in the costs for fillet improvements, it has been concluded that there will be no costs attributable to the B-2707 for holding apron modification.

A considerable amount of rigid-pavement inlay has been placed in the terminal-area pavements at San Francisco. It is assumed that such pavements will be required for the B-2707. Accordingly, a cost per gate position is estimated in Par. 4.15.5 on the basis given in Par. 4.2.3.

4.15.3 Evaluation of Structures
Available data indicate that all pipes and conduits beneath airfield pavements, including the battery of culverts carrying the South Airport Canal under the threshold of runway 1R, are within the range of acceptable conditions stated in Par. 4.2.3.

4.15.4 Terminal Area Considerations
The San Francisco terminal area comprises two concourse-connected central terminal buildings (Fig. 4-32). Three passenger-loading piers extend from each of the central terminal buildings onto the aircraft parking apron. There are satellite buildings at the outer ends of piers B, G, and F; pier D is T-shaped; piers E and G are linear. Pier F has a Y-shape, with satellites at both extremities of the arms of the Y. The older of these is designated pier F; the satellite now under construction is designated pier FF. The master plan for the terminal area includes a third central terminal building from the center of which will extend a Y-shaped pier (pier A) having satellites at its extremities. When completed, the arc enclosed by the interconnected terminals will be 270 degrees. The B-2707 can be readily accommodated at a minimum of 13 apron parking positions (Fig. 4-32). The most convenient parking modes appear to be parallel and canted. Three positions would be simultaneously available at pier G, which handles international flights: one each at piers B and FF, and two each at the remaining piers. The particular arrangements selected have been investigated for maneuvering convenience, availability of adjacent gate positions, and adaptability to existing gate arrangements and loading procedures.

Both second-level loading bridges and mobile ramps are employed by the airlines at San Francisco. The second-level devices include fixed-bridge nose-loaders and swinging-telescoping bridges. At piers B, C, and F, modification of the existing swinging-telescoping bridges will be required to reach the B-2707 second-door sill heights. For the B-2707 position at piers D, F, FF, and G, the existing or planned nose-loaders will have to be replaced by swinging-telescoping type loaders. The cost has been estimated and the results are summarized in Par. 4.15.5.

Hydrant fueling systems have been installed at all piers except pier E. The system at pier D is no longer in use, owing to a parking rearrangement. For the purposes of this study, the systems at piers B, C, F, and G have been considered. The existing laterals at piers B and C will accommodate the demand of 2,000 gpm at each fueling point for the positions shown, but new hydrants will have to be provided. The planned revamping of the parking positions at pier D and the accompanying alterations to the fueling system are not considered attributable to the costs of the B-2707. At pier F and pier FF, which are now under construction, it has been assumed that new laterals and hydrants will be provided for the three B-2707 positions shown. Three oil companies serve the positions at the International Building, pier G. The existing 12-in. loop for one company is located in such a manner that the three positions can be served with laterals stubbed off each side of the loop. Three sets of B-2707 hydrants will be needed for each position.

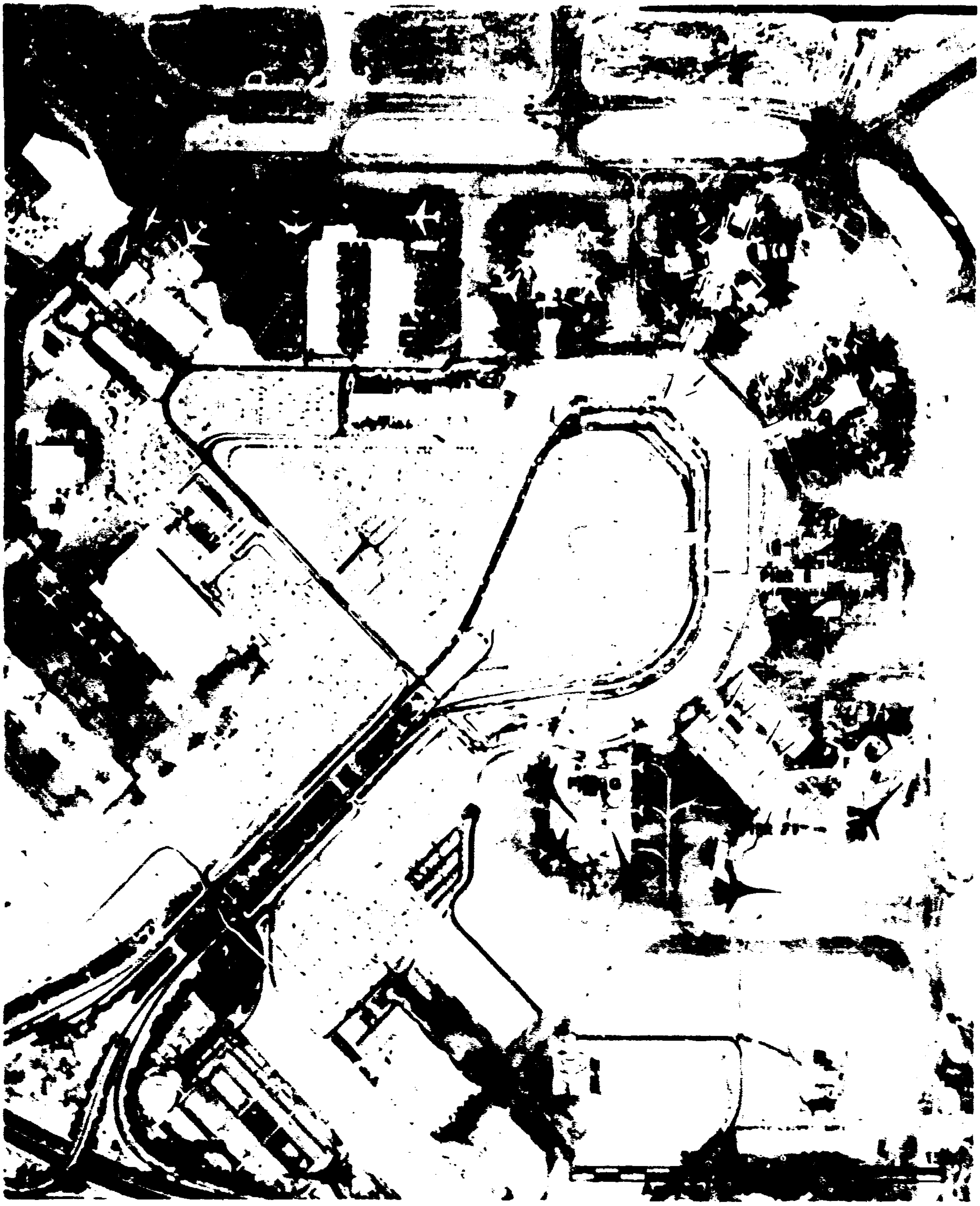

Figure 4-32. San Francisco Terminal Area

4.15.5 Estimated Costs

a. Lump Sum Items

	High	Best
Taxiway overlays at \$1.20 per sq yd	\$540,000	0
Modification to 20 fillets and 2 curved taxiways:		
Full-strength pavement at \$12 per sq yd	61,000	\$ 61,000
Shoulder pavement	35,000	35,000
Revisions to lights and signs	24,000	24,000
Total Estimated Costs	\$660,000	\$120,000

b. Unit Costs Per Gate Position

Passenger loading devices	\$ 68,000
Fuel system modifications	22,000
Terminal apron inlays	30,000

4.16 SEATTLE-TACOMA INTERNATIONAL AIRPORT

4.16.1 Evaluation of Pavements

All pavements at this airport, with the exception of certain pavements which will receive little or no usage by the B-2707 at maximum ramp weight, are rigid or pavements with bituminous overlays on a rigid base (Fig. 4-33). A modulus of subgrade reaction (k) of 300 was used for the design of the rigid pavement.

The locations of the different pavement sections are as follows:

- 12-in. rigid pavement -- 2500-ft length at each end of existing runway 16-34 and the three holding aprons, 10,000-ft length of taxiway 6, and the southeast terminal apron
- 10-in. rigid pavement -- the majority of the terminal area, taxiway 3, and 1900 ft of taxiway 6
- 6-in. rigid pavement with 5-in. bituminous overlay -- remaining length of portion of runway 16-34
- 6-in. rigid pavement with 8-in. bituminous overlay -- remaining interior portion of runway 16-34
- 6-in. rigid pavement with 6-in. crushed stone base and 4-in. bituminous overlay -- runway 2-20

The flexural stresses induced by the DC-8-55 are everywhere higher than those that would be induced by the B-2707. The costs of any necessary pavement improvements would thus not be attributable to the B-2707.

4.16.2 Requirements for New Pavements

The geometry of the pavement intersection fillets was taken from detailed site plans made available by the airport operator and verified from an aerial photograph. Fifty-two fillets were studied, five of which would require improvements. The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in Par. 4.2.3.

The specific assumptions made for the investigation are as follows:

- Existing 2-20 will almost certainly be decommissioned prior to the introduction of the B-2707
- The terminal apron depth is such that relatively wide, sweeping turns may be made from the entering taxiways without interfering with parked aircraft
- Several of the old runways may be used as taxiways

The holding aprons at the runway 16 threshold and the supplementary apron located approximately 1700 ft from the threshold of runway 34 both conform to criteria outlined in Par. 4.2.3.

If the criteria of Par. 4.2.3 are observed, the runway 34 holding apron will have to be widened. The required enlargement would be accomplished by replacing 25 ft of the existing 50-ft-wide shoulder with full-strength pavement. To maintain the existing 50-ft shoulder under conditions of B-2707 usage would otherwise require a fill approximately 40-ft high. The cost of this fill was not considered practical and the allocated cost is based upon the more economical solution.

Figure 4–33. Seattle–Tacoma International Airport

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4.16.3 Evaluations of Structures

The southward extension of runway 16-34 required the construction of a subway to carry South 188th Street beneath the runway and its parallel taxiway. The subway is reinforced concrete, two-span, rigid frame with clear interior spans of 33 ft, 6 in. Reinforced concrete struts spaced at 10 ft on centers in the subgrade brace the footings of the exterior legs of the frame against the forces of lateral earth pressure. The minimum depth of cover above the top of the subway at the runway and taxiway crossings is about 8 ft. The structure was designed for an airplane-imposed live loading of 600,000 lb. An analysis was made of stresses in the frame and its footings and of pressures on the soil under its footings resulting from the passage of the B-2707 on the pavement above. All conditions were found to be satisfactory.

Available data indicates that all pipes and conduits beneath airfield pavements are within the range of conditions stated in Par. 4.2.3 and are compatible with the B-2707.

4.16.4 Terminal Area Considerations

The terminal area is based upon the central terminal and finger pier concept. Present planning for the terminal calls for four concourses, diverging at 90 degrees from each other at the north and south ends of the main building.

Concourse B, after extending SSE from the central terminal for some distance, bears 45 degrees so that its outer face parallels the north-south runway. Concourse C when completed will be a mirror image of Concourse B if the existing master plan remains unchanged. Studies were made of the four existing concourses, and it was determined that the B-2707 could readily be accommodated at each. Figure 4-34 shows eight B-2707's at those gate positions where it is feasible for the airplane to be docked and maneuvered by conventional techniques. Owing to the unusually large apron space available in the terminal area, it is feasible to park nose-in. The use of this parking mode minimizes the B-2707 encroachment on adjacent parking positions, which can be occupied by subsonic or piston-engine airplanes. The parking positions shown on Fig. 4-34 have been investigated as to maneuvering convenience, effects on the availability of adjacent gate positions, and adaptability to existing gate arrangements and loading procedures.

The airlines at Seattle employ both second-level loading devices and mobile ramps. The second-level devices include swinging nose-loaders, fixed-bridge nose-loaders, and swinging-telescoping bridges.

None of the current loading devices can be used for nose-in loading to both forward doors. The costs of a nose-loading device capable of two-door loading have been estimated.

From plans furnished by the Port of Seattle Commission, the existing apron supply-points have been compared with the requirements of the supersonic transport. Underground hydrant fueling facilities have been installed at concourse D, concourse C, and at the interior positions on the west side of concourse B. In order to service the proposed B-2707 positions at concourses B and D, it will be necessary to provide new lateral lines to the fueling points and new hydrants. Any future addition of a fueling system on concourse A would not be deemed chargeable to the B-2707. At concourse C, each of the two B-2707 positions shown would require a new lateral and two new hydrants.

4.16.5 Estimated Costs

a. Lump Sum Items

Modification of 5 fillets:	
Full-strength pavement at $11 per sq yd	$ 11,000
Shoulder pavement	4,000
Revision to lights and signs	4,000
Widening of runway 34 holding apron:	
Full-strength pavement at $11 per sq yd	22,000
Revisions to lights	2,000
Total Estimated Costs	$ 43,000

b. Unit Cost Per Gate Position

Passenger loading devices	$150,000
Fuel system modifications	11,000

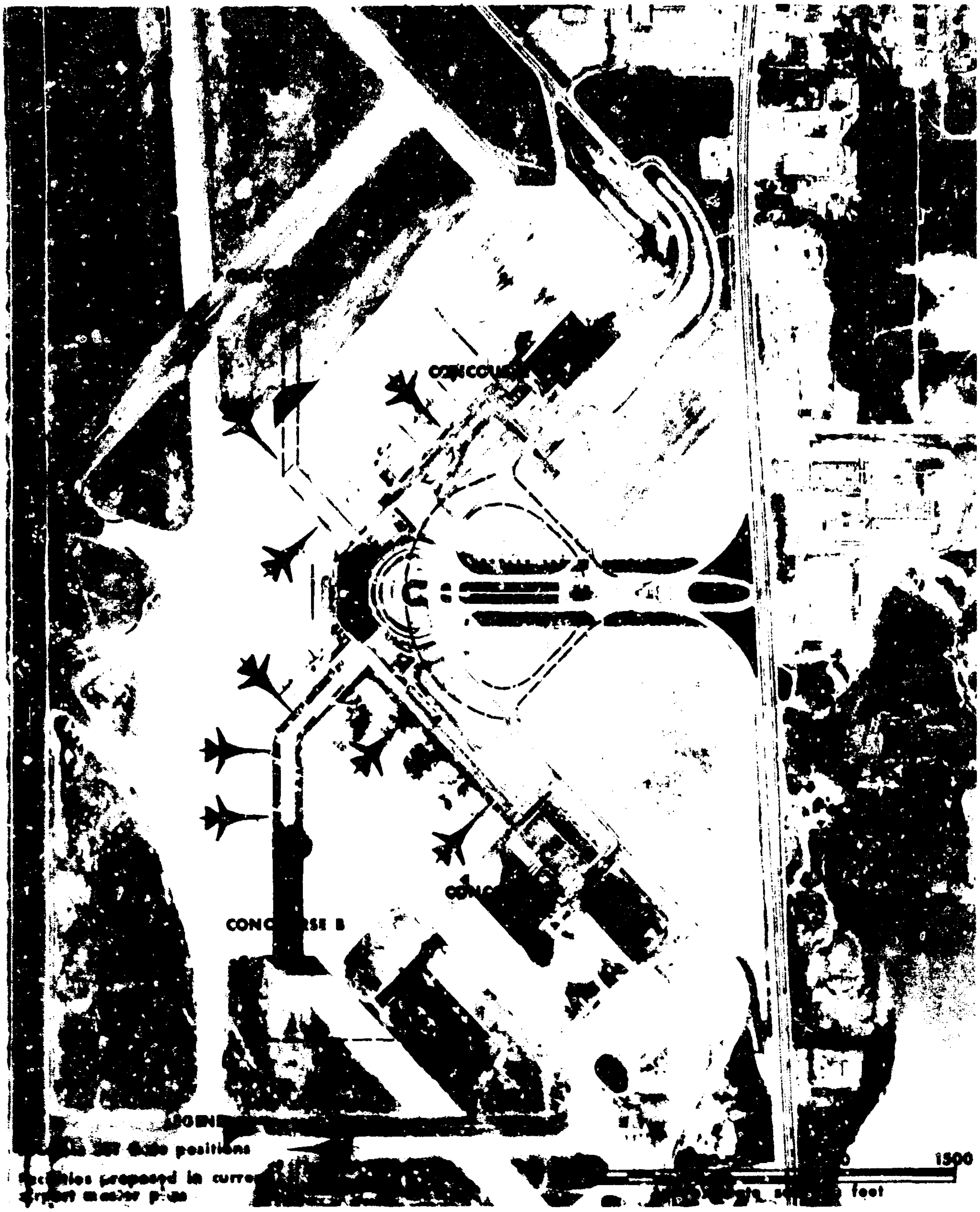

Figure 4-34. Seattle-Tacoma Terminal Area

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4.17 DULLES INTERNATIONAL AIRPORT, WASHINGTON, D.C.

4.17.1 Evaluations of Pavements

All pavements at Dulles International Airport shown in Fig. 4-35 are concrete. They are designed for aircraft of 500,000 lb gross weight and are 15-in. thick on taxiways, aprons, the critical sections of runways, and the central 100 ft of the noncritical sections of runways. The outer 25-ft strips of the noncritical sections of the runways are 12-in. thick. Engineers of the Bureau of National Capital Airports recommend the use of a modulus of subgrade reaction of k = 260 and maximum allowable flexural stress of 500 psi for the 15-in. thick pavements and 680 psi for the 12-in. thick pavements. The calculated stresses that would be induced by the B-2707 are 65 percent and 60 percent, respectively, of the allowable for the 15-in. and 12-in. pavements. The B-2707 will be compatible with those pavements.

4.17.2 Requirements for New Pavements

A total of 134 fillets and 1 curved taxiway were investigated, of which 17 fillets would require improvements. The general assumptions and criteria leading to the standards adopted for the present evaluation may be found in Par. 4.2.3. Costs of fillet improvements have been estimated, using current construction costs, with results summarized in Par. 4.17.5. The specific assumptions made for the investigation of the fillets at Dulles are as follows:

a. Consecutive turns of 90 degrees between parallel taxiways are rarely made.

b. Certain cross taxiways near the terminal apron between parallel taxiways are intended for future terminal expansion and are rarely used.

c. It was assumed that taxiways to both ends of runways 1R-19L and 1L-19R will be used.

This conservative approach, which preserves flexibility in operations, approximately doubles the cost attributable to the B-2707 for fillet modification. Both the holding apron serving runway 19L and the apron serving runways 1L and 30 are adequate by the criteria outlined in Par. 4.2.3.

4.17.3 Evaluation of Structures

Available data indicates that all pipes and conduits beneath airfield pavements are characterized by the range of acceptable conditions stated in Par. 4.2.3.

4.17.4 Terminal Area Considerations

The airport's method of passenger loading, which brings passengers to an airplane rather than the airplane to the terminal, utilizes the mobile lounge, a system which is readily adaptable to the B-2707. Since the B-2707 does not have to maneuver into normally constricted terminal areas, the only requirement for compatibility is that the mobile lounge be able to mate with the airplane. The mobile lounge will be able to reach the forward two doors with lounge modifications so minor, no costs are assessed against the B-2707 for passenger loading devices.

The airplane parking aprons (Fig. 4-36) are served by a hydrant fueling system, with fuel supplied by two 8-in., two 12-in., and one 14-in. header mains. The pressures and pumping capacities of the system have been found adequate for the demands of the B-2707, but the hydrants and lateral fuel pipes are not of sufficient size. The cost of modification typical for the fueling layout is included in Par. 4.17.5. This cost will reflect four hydrants and two lateral lines per gate position.

4.17.5 Estimated Costs

a. Lump Sum Items

Modifications to 17 fillets:

Full-strength pavement at $15 per sq yd	$159,000
Shoulder pavement	45,000
Revisions to lights and signs	26,000
Total Estimated Costs	$230,000

b. Unit Costs Per Gate Position

Fuel system modifications	$ 16,000

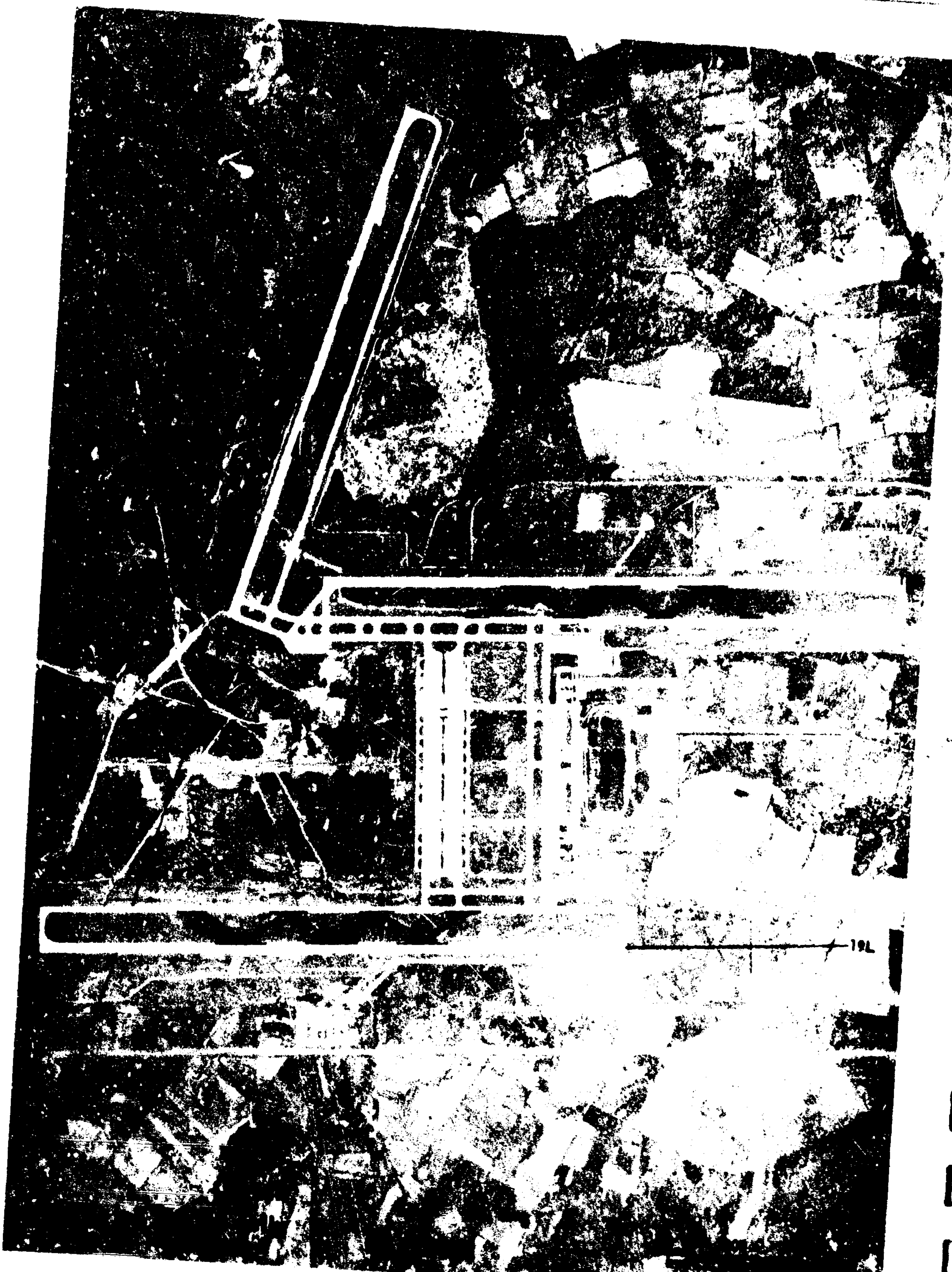

Figure 4–35. Dulles International Airport, Washington D.C.

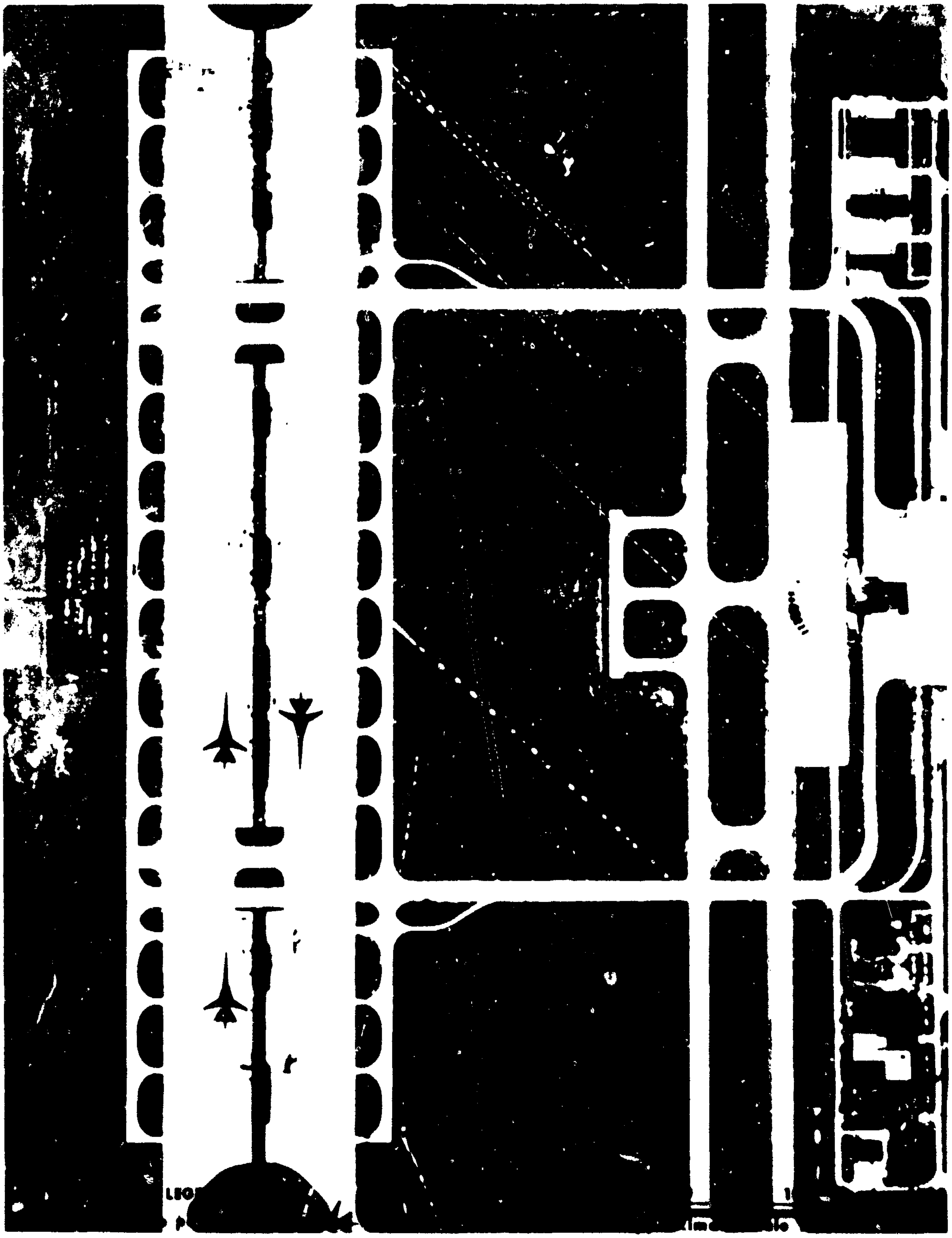

Figure 4-36. Dulles Terminal Area

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CONTENTS

5.0 OPERATIONAL INTEGRATION PROGRAM

5.1 PROGRAM DEFINITION

The objective of the operational integration program is to assure, through appropriate events and actions, that the B-2707 will fit into the existing worldwide and domestic air transportation system. The program plan identifies tasks, responsibilities, and schedules for the following:

a. Timely development of operational support requirements, equipments, facilities and procedures

b. Demonstrations to verify airplane operational suitability

c. Timely training of personnel

d. Required coordination activities, primarily with the airlines, airport operators, and FAA to implement the program

To achieve operational integration, consideration must be given to all elements of the B-2707 system (Fig. 5-1). The airplane elements displayed in the figure are reported in the documents of Airplane Technical, Vol. II. The design, substantiated therein, considered and incorporated requirements for operational integration. Sections 2.0 through 4.0 of this document cover the operational integration work to date, relative to this design, on mission flexibility, environment integration, and airport suitability. These data on design and integration provide the baseline upon which subsequent phases of system integration may proceed. Refinements to system definition will be made in Phase III to improve and implement operational requirements as they continue to be developed.

Figure 5-2 shows the relationship of major activities of the B-2707 program. Operational integration is that part of this program which deals with the operational characteristics of the system. Figure 5-3 shows the basic steps in the operational integration program. The B-2707 design, which is configured to provide excellent payload performance, provides a balance with the necessary operational characteristics such as pilot handling, airlines' operational and maintenance requirements and passenger comfort—but none of these at sacrifice of safety.

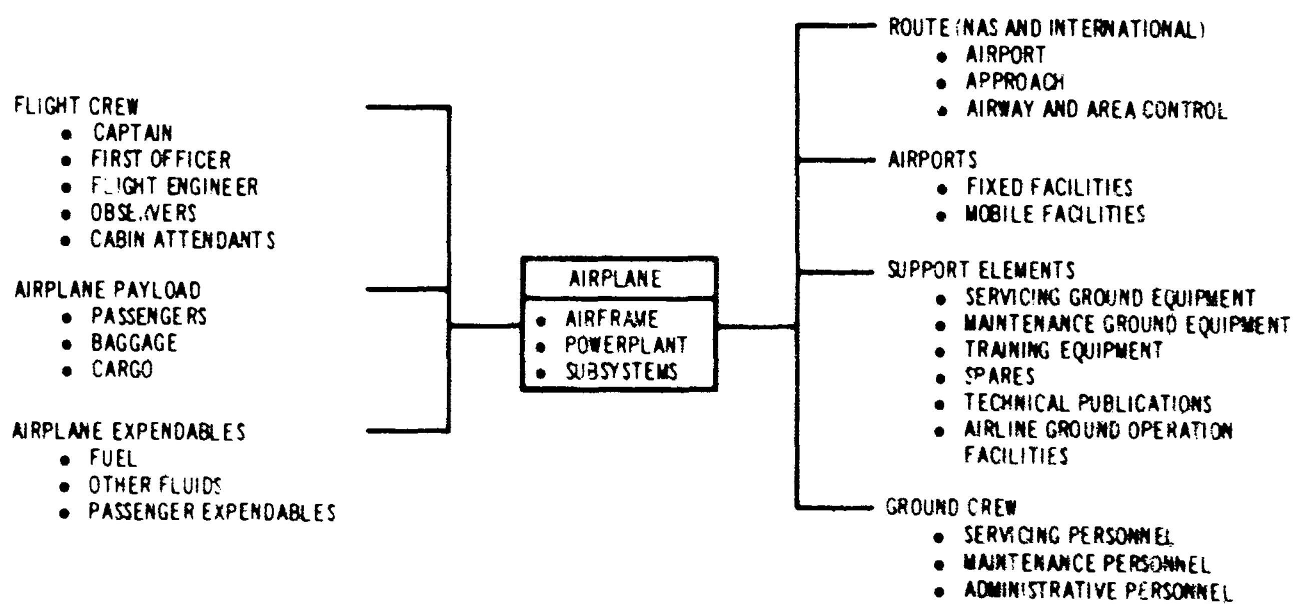


Figure 5-1. B-2707 System Elements

Operational integration requires the combined effort of the airlines, airport operators, FAA, airframe and engine contractors, and other agencies. Within the company, operational integration requires the coordinated activities of all groups of the engineering department.

Definition of operational requirements, design and operational solutions and demonstration of compliance with the requirements is the basis for the programs discussed in following sections and in the other plans shown on the matrix of Fig. 5-5. Essentially, operational integration encompasses activities described in the many individual plans and in the statement of work. Where appropriate, these other plans are discussed in this document. The Airport Suitability-Operational Facilities Plan is included in its entirety.

5.2 MANAGEMENT APPROACH

The operational integration program will be conducted within the framework of the organization structure described in Program Management, V5-B2707-8. Figure 5-4 identifies the basic organization responsibilities. The many facets of the operational integration program are assigned to, and performed by, individual functional organizations as shown in Fig. 5-5. In this manner, the operational integration and design and analysis are carried out concurrently. Each organization will, as appropriate: (1) be responsible for requirements determination, (2) provide technical support—design and analysis, (3) be responsible for demonstration or measure of integration, and (4) monitor demonstration and assure compliance with requirements. With important additional activities discussed below, the matrix (Fig. 5-5) indicates the means by which the elements of the program will be executed.

5.2.1 Operational Integration Responsibility

Because of the importance of operational integration, engineering management has the primary responsibility for this function as it has on all commercial airplane programs of the Boeing Company. It is assisted by System Integration and Configuration Development for coordination and for duties defined subsequently.

5.2.2 Requirements

Management approves the requirements, many of which are developed through the individual plans and activities. These requirements are documented in the Model Specification and Subsystem Specifications and other documentation. These include normal operational requirements plus those for abnormal and emergency situations. System Integration and Configuration Development provides the bridge between integration requirements and design. As part of their basic responsibility for system engineering configuration development, they will study the economic, design, and system operational requirements. Analyses are made to resolve conflicts between several requirements and between any requirements and design. Recommended solutions form the basis for management approval of requirements set forth for B-2707 design.

5.2.3 Management Reviews

A further means of control over the process of operational integration is provided through design reviews chaired by engineering management. These reviews consist of critical design reviews, mockup inspections, and hardware inspections. These reviews plus the processes of configuration management (Configuration Management Plan, V5-B2707-1) and product assurance (Quality Assurance Program, V4-B2707-21) provide visibility and status for ascertaining that operational, economic, and design requirements are accommodated in the design.

5.2.4 Coordination

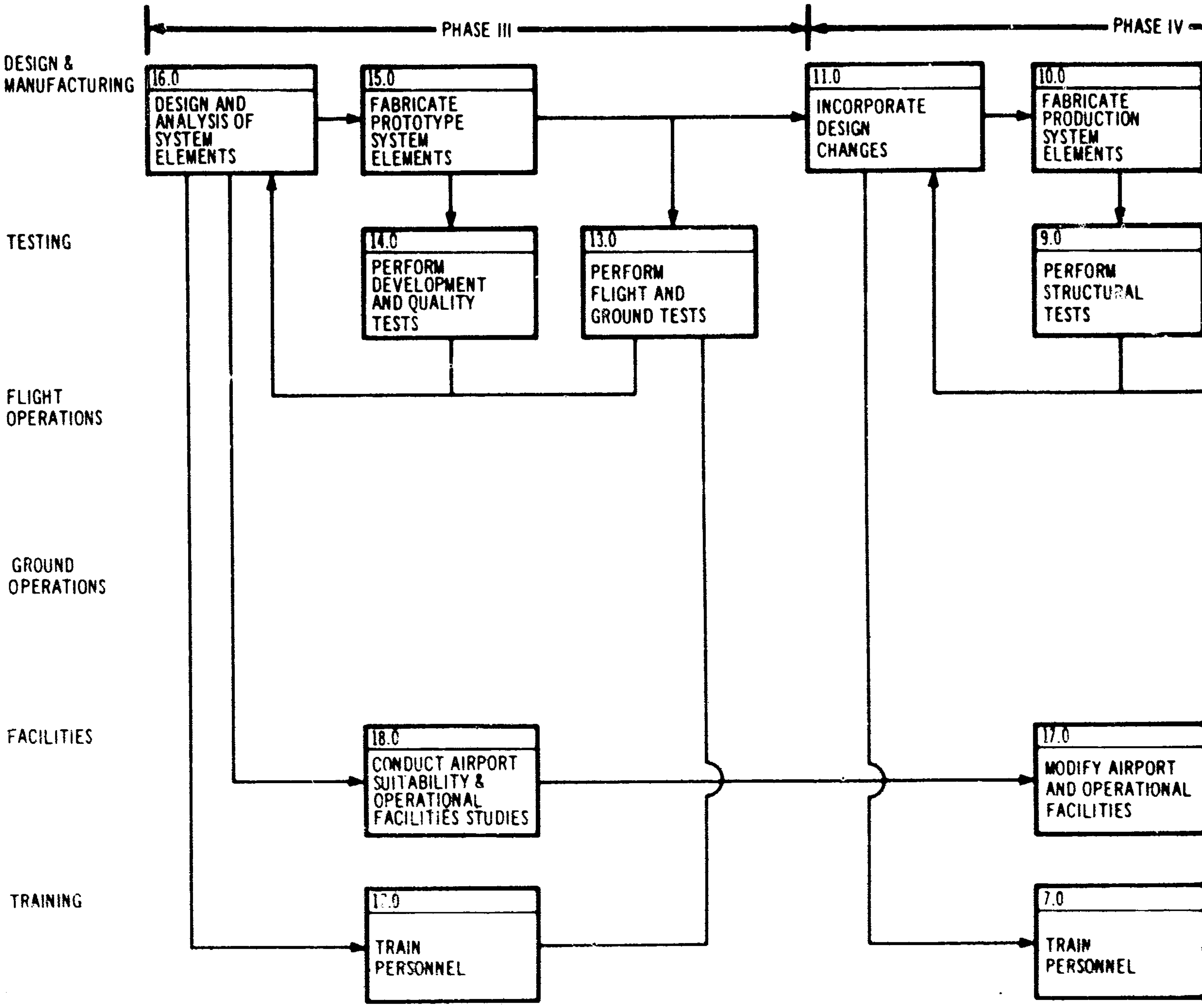
Management will, through its organizational structure, provide the necessary coordination interfaces with the FAA, airports, and airline operators (See Product Support Plan, V4-B2707-20 for airline coordination plan.) In addition, coordination will be maintained with associations, subcommittees, industry and other Governmental agencies. To assure commonality where appropriate between the B-2707 and existing Boeing subsonic jets and the 747 airplane, cognizant engineers from the SST program have been assigned specific coordination tasks.

5.2.5 Status

Schedules and status of the operational integration program will be maintained and reported in accordance with the procedure defined in the Cost and Schedules Control Plan, V5-B2707-6. The Operational Integration Program Plan will be updated on a six-months basis.

5.2.6 Unique Responsibilities

The project pilot plays a strong part throughout all phases of the integration program. He coordinates directly with FAA and airline pilots. He advises from a piloting standpoint, provides feedback from flight simulator programs and the flight



THE SUPERSONIC TRANSPORT (SST) IS AN INTERCONTINENTAL TRANSPORT WHICH IS ECONOMICALLY COMPETITIVE WITH EXISTING SUBSONIC AIRCRAFT AND COMPATIBLE WITH EXISTING AIRPORTS, NAVIGATION AND TRAFFIC CONTROL SYSTEMS.
PLACING THE SST INTO OPERATION INVOLES DESIGN, FABRICATION, TEST, OPERATION, MAINTENANCE AND TRAINING. THE RELATIONSHIP OF THESE FUNCTIONS IS SHOWN ON THIS DIAGRAM.
THE FORMAL SYSTEMS ANALYSIS DOCUMENTED IN D6A10246-1 SYSTEM FUNCTIONAL ANALYSIS - SUPERSONIC TRANSPORT EXPANDS BLOCKS NO. 1.0 AND 2.0.

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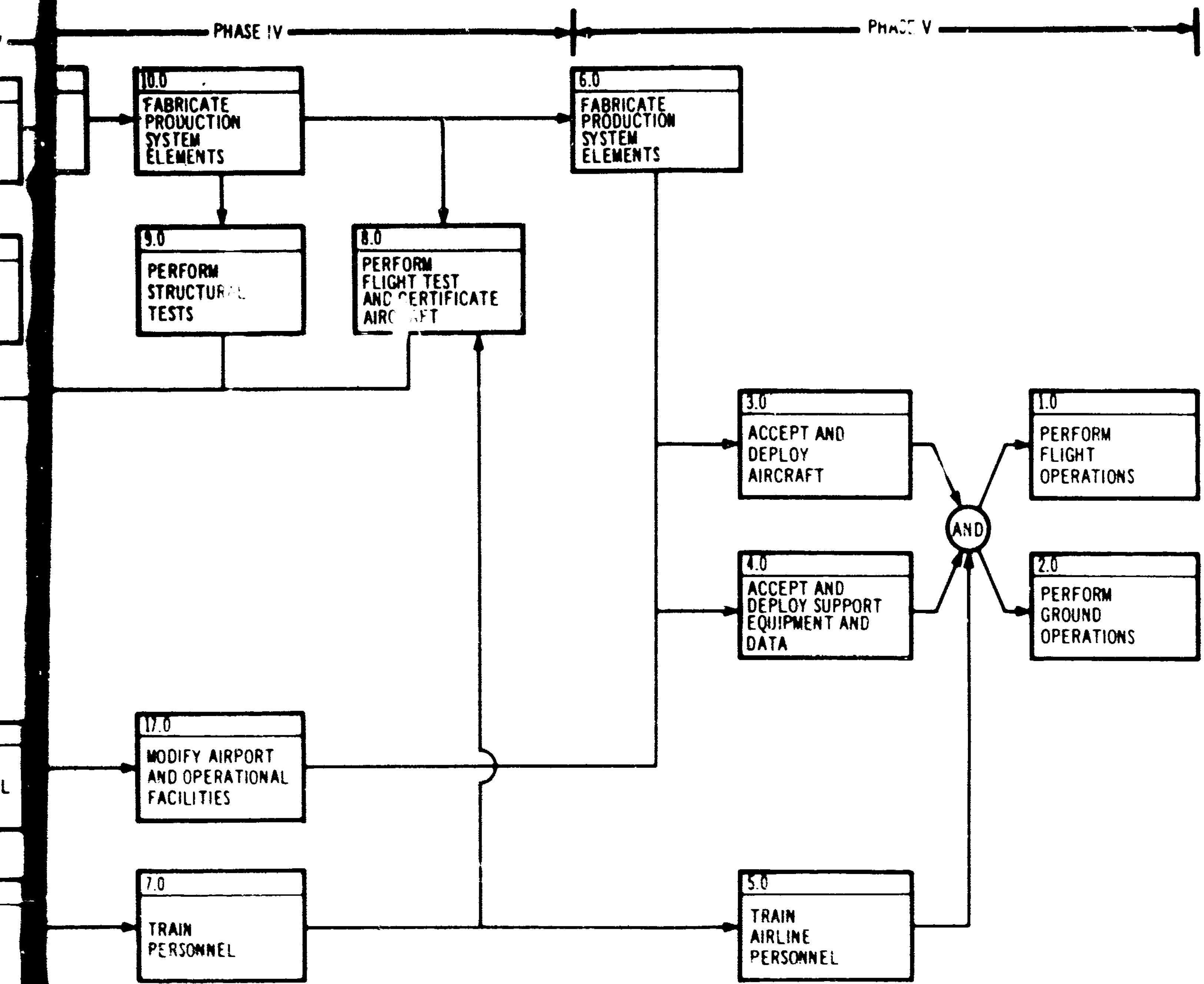
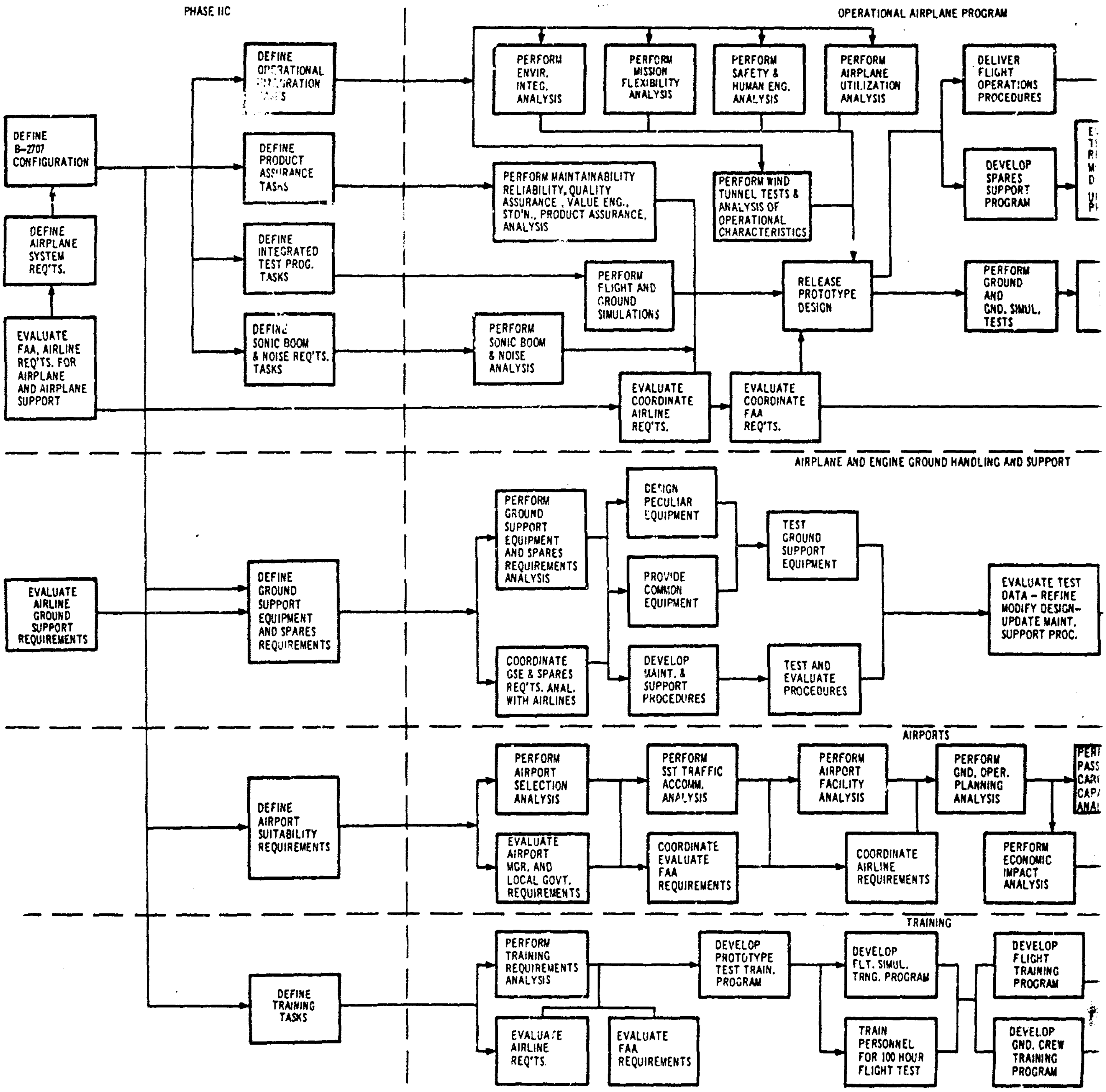


Figure 5-2. Top Functional Diagram Supersonic Transport


PHASE IIC
OPERATIONAL AIRPLANE PROGRAM
DEFINE B-2707 CONFIGURATION
DEFINE AIRPLANE SYSTEM REQ'TS.
EVALUATE FAA, AIRLINE REQ'TS. FOR AIRPLANE AND AIRPLANE SUPPORT
DEFINE OPERATIONAL INTEGRATION TASKS
DEFINE PRODUCT ASSURANCE TASKS
DEFINE INTEGRATED TEST PROG. TASKS
DEFINE SONIC BOOM & NOISE REQ'TS. TASKS
PERFORM ENVIR. INTEG. ANALYSIS
PERFORM MISSION FLEXIBILITY ANALYSIS
PERFORM SAFETY & HUMAN ENG. ANALYSIS
PERFORM AIRPLANE UTILIZATION ANALYSIS
DELIVER FLIGHT OPERATIONS PROCEDURES
PERFORM MAINTAINABILITY RELIABILITY, QUALITY ASSURANCE, VALUE ENG., STD'N., PRODUCT ASSURANCE, ANALYSIS
PERFORM WIND TUNNEL TESTS & ANALYSIS OF OPERATIONAL CHARACTERISTICS
DEVELOP SPARES SUPPORT PROGRAM
PERFORM FLIGHT AND GROUND SIMULATIONS
RELEASE PROTOTYPE DESIGN
PERFORM GROUND AND GND. SIMUL. TESTS
PERFORM SONIC BOOM & NOISE ANALYSIS
EVALUATE COORDINATE AIRLINE REQ'TS.
EVALUATE COORDINATE FAA REQ'TS.
AIRPLANE AND ENGINE GROUND HANDLING AND SUPPORT
EVALUATE AIRLINE GROUND SUPPORT REQUIREMENTS
DEFINE GROUND SUPPORT EQUIPMENT AND SPARES REQUIREMENTS
PERFORM GROUND SUPPORT EQUIPMENT AND SPARES REQUIREMENTS ANALYSIS
COORDINATE GSE & SPARES REQ'TS. ANAL. WITH AIRLINES
DESIGN PECULIAR EQUIPMENT
PROVIDE COMMON EQUIPMENT
DEVELOP MAINT. & SUPPORT PROCEDURES
TEST GROUND SUPPORT EQUIPMENT
TEST AND EVALUATE PROCEDURES
EVALUATE TEST DATA – REFINE MODIFY DESIGN– UPDATE MAINT. SUPPORT PROC.
AIRPORTS
DEFINE AIRPORT SUITABILITY REQUIREMENTS
PERFORM AIRPORT SELECTION ANALYSIS
EVALUATE AIRPORT MGR. AND LOCAL GOVT. REQUIREMENTS
PERFORM SST TRAFFIC ACCOMM. ANALYSIS
COORDINATE EVALUATE FAA REQUIREMENTS
PERFORM AIRPORT FACILITY ANALYSIS
COORDINATE AIRLINE REQUIREMENTS
PERFORM GND. OPER. PLANNING ANALYSIS
PERFORM ECONOMIC IMPACT ANALYSIS
TRAINING
DEFINE TRAINING TASKS
PERFORM TRAINING REQUIREMENTS ANALYSIS
EVALUATE AIRLINE REQ'TS.
EVALUATE FAA REQUIREMENTS
DEVELOP PROTOTYPE TEST TRAIN. PROGRAM
DEVELOP FLT. SIMUL. TRNG. PROGRAM
TRAIN PERSONNEL FOR 100 HOUR FLIGHT TEST
DEVELOP FLIGHT TRAINING PROGRAM
DEVELOP GND. CREW TRAINING PROGRAM

A

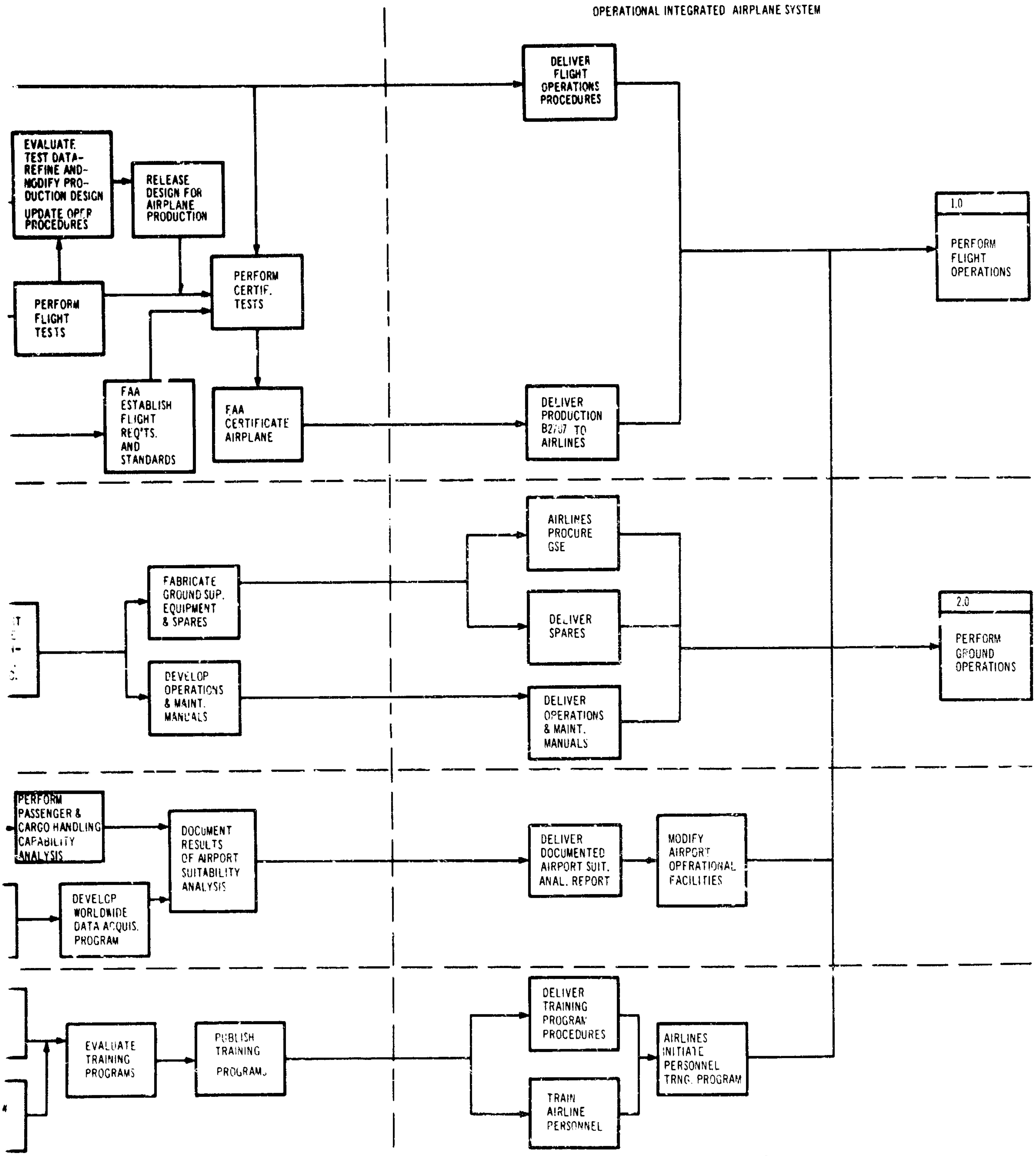
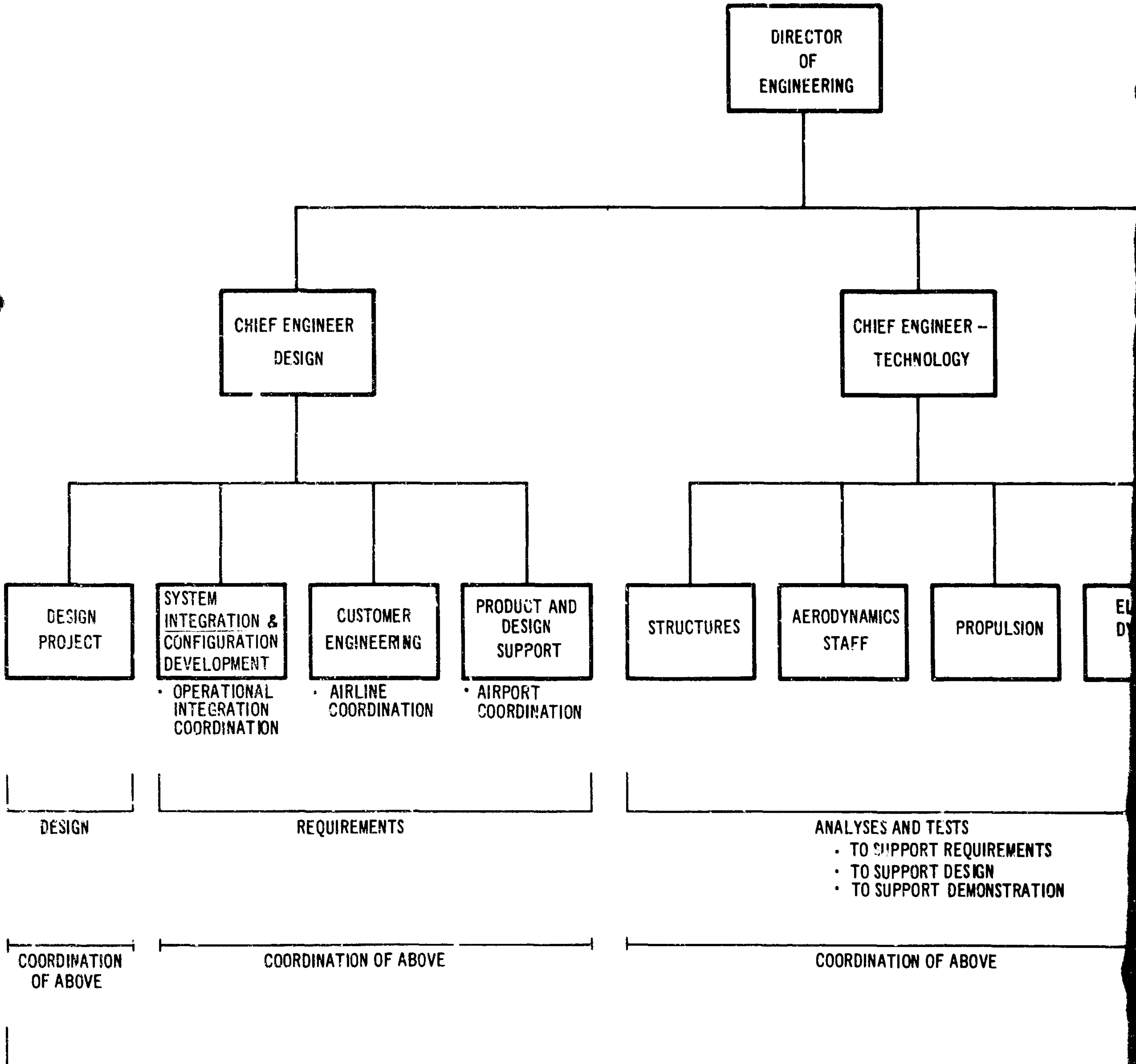


Figure 5-3. Operational Integration



OPERATIONAL INTEGRATION FUNCTIONS AND RESPONSIBILITIES

Figure 5-4.

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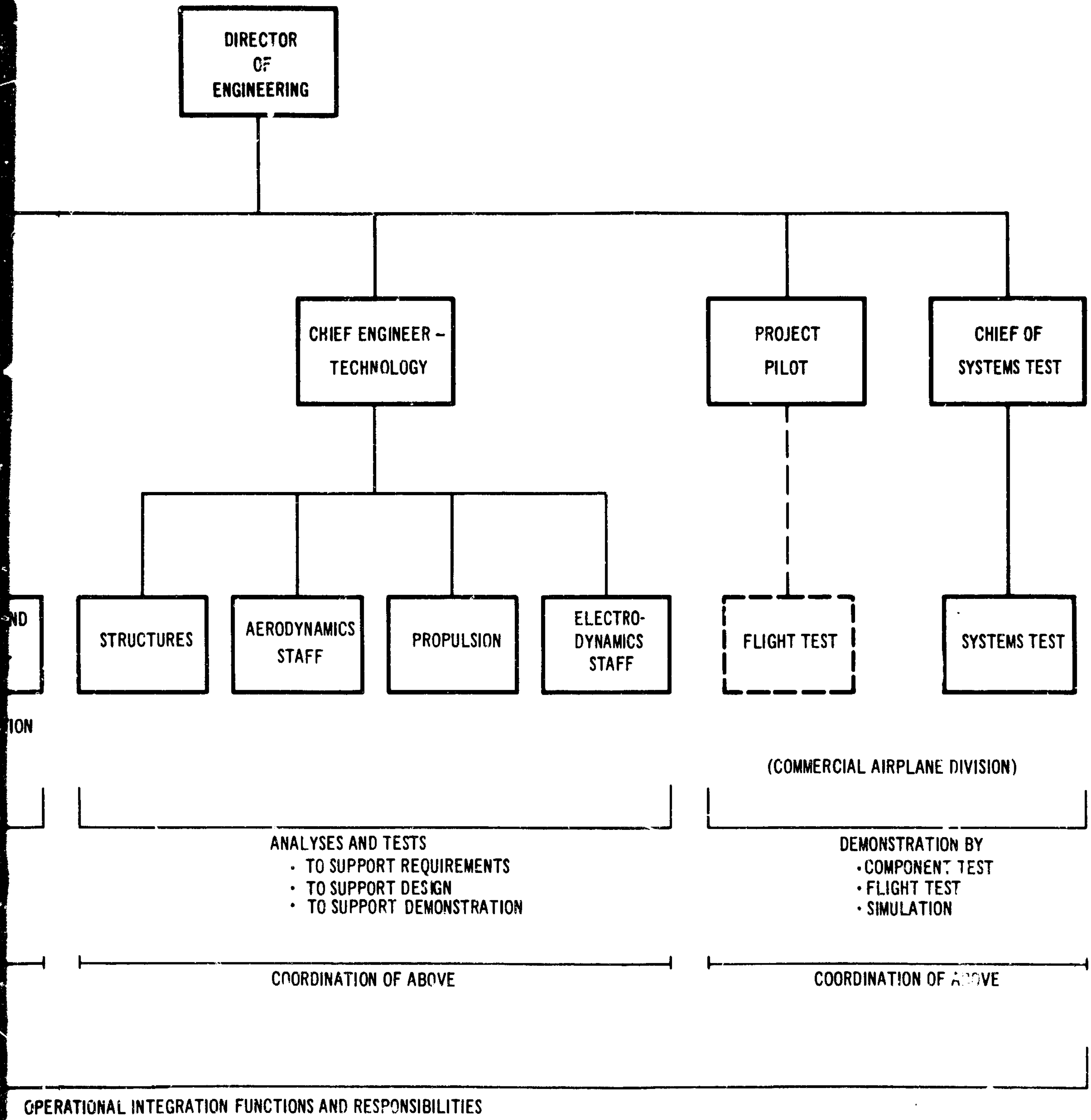

Figure 5-4. Operational Integration Organization

1 RESPONSIBLE FOR REQUIREMENTS DETERMINATION.
2 TECHNICAL SUPPORT--DESIGN AND ANALYSIS.
3 RESPONSIBLE FOR DEMONSTRATION OR MEASURE OF INTEGRATION
4 MONITOR DEMONSTRATION AND ASSURE COMPLIANCE WITH REQUIREMENTS

INTEGRATION ELEMENTS / RESPONSIBILITY AND AUTHORITY	DOCUMENT REFERENCE	PROJECT PIL			
A. OPERATIONAL INTEGRATION					
1. FLIGHT OPERATIONS	V4-B2707-1				
PILOT VISIBILITY		2	1		
NORMAL, ABNORMAL AND EMERGENCY PROCEDURES		3	1		
PERFORMANCE MARGINS		3			3
OFF-DESIGN OPERATIONS		3			
MIDPOINT EMERGENCIES AND FAILURES		3			
FUEL REQUIREMENTS		3			
MINIMUM EQUIPMENT REQUIREMENTS		3			
THREE ENGINE FERRY PROCEDURE		3	1		
NOISE ABATEMENT PROCEDURES		3			
ALL WEATHER LANDING CAPABILITY & PROCEDURES			4		
GROUND ENVIRONMENT FLEXIBILITY		2			
2. ENVIRONMENT INTEGRATION	V4-B2707-1				
TURBULENCE		3			
OZONE, RADIATION, PARTICULATE					
NATIONAL AIRSPACE SYSTEM COMPATIBILITY					
A/C & ENGINE GROUND HANDLING & SUPPORT					
3. AIRPORT SUITABILITY	V4-B2707-1				
4. SONIC BOOM PROGRAM	V4-B2707-3	3			

A

IBILITY HORITY	DOCUMENT REFERENCE	PROJECT PILOT			SYSTEMS TEST			SYSTEM INTEGRATION AND CONFIGURATION DEVELOPMENT			STRUCTURES DESIGN			SYSTEMS DESIGN			PROPULSION DESIGN			INTERIORS DESIGN			DESIGN SUPPORT			PRODUCT SUPPORT			AE	
	V4-B2707-1																													
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		3						4																		2			3	1
RES			4											3	2	4							2			2	4		1	1
		2						4						2			2						2			3	1			
ON	V4-B2707-1																													
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								4						3	1															
								4															4			3	1			
	V4-B2707-[illegible]							2						2						2			2			3	1	2		
	V4-B[illegible]	[illegible]			[illegible]			4																					3	1

INTERIORS DESIGN			DESIGN SUPPORT			PRODUCT SUPPORT			AERODYNAMICS STAFF			PROPULSION-MECHANICAL STAFF			STRUCTURES STAFF			ELECTRODYNAMICS STAFF			FLIGHT TEST			CUSTOMER ENGINEERING		
2			2																		2			2		
			2			2	1		3												3			2		
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									3	1								3	1		3					

Figure 5-5. System Integration Responsibilities

1 RESPONSIBLE FOR REQUIREMENTS DETERMINATION.
2 TECHNICAL SUPPORT—DESIGN AND ANALYSIS.
3 RESPONSIBLE FOR DEMONSTRATION OR MEASURE OF INTEGRATION.
4 MONITOR DEMONSTRATION AND ASSURE COMPLIANCE WITH REQUIREMENTS.

INTEGRATION ELEMENTS / RESPONSIBILITY AND AUTHORITY	DOCUMENT REFERENCE	PROJECT PILOT			
A. (CONTINUED)					
5, AIRPORT & COMMUNITY NOISE PROGRAM	V4-B2707-4	3			3
6. INTERNAL NOISE PROGRAM	V4-B2707-5				
7. SYSTEM SAFETY PROGRAM	V4-B2707-6				
8. TRAINING, TRAINING EQUIPMENT PROGRAM	V4-B2707-7	2	1		
9. HUMAN ENGRG PROGRAM	V4-B2707-8				
B. ADDITIONAL SYSTEM INTEGRATION ELEMENTS					
1. TEST INTEGRATION MANAGEMENT	V4-B2707-10				
TEST INTEGRATED PROGRAM	V4-B2707-11				3
SIMULATION PROGRAM	V4-B2707-12	3	1		3
FLIGHT SIMULATION PROGRAM	V4-B2707-13	3	1		3
FLIGHT TEST PROGRAM	V4-B2707-14	3			3
2. PRODUCT ASSURANCE					
MAINTAINABILITY PROGRAM	V4-B2707-15				
RELIABILITY PROGRAM	V4-B2707-16				
QUAL. ASSUR. PROGRAM	V4-B2707-17				2
VALUE ENGRG PROGRAM	V4-B2707-18				
STANDARDIZATION PROGRAM	V4-B2707-19				
PRODUCT SUPPORT PROGRAM	V4-B2707-20	2			2

A

SYSTEMS TEST			SYSTEM INTEGRATION AND CONFIGURATION DEVELOPMENT			STRUCTURES DESIGN			SYSTEMS DESIGN			PROPULSION DESIGN			INTERIORS DESIGN			DESIGN SUPPORT			PRODUCT SUPPORT			AERODYNAMICS STAFF			PROPULSION-MECHANICAL STAFF			STRUCTURES STAFF			ELECT…		
3			4																					3	1		3						3	1	
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3			4			2	1		2	1		2	1		2			2			2			2	1		2			2			2		
			4			2			2			2			2			3	1		2			2			2			2			2		
			4			2			2			2			2			3	1		2			2			2			2			2		
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			4			2			2			2			2			3	1		2			2			2			2			2		
			4			2			2			2			2			3	1		2			2			2			2			2		
2			4			2			2			2			2			4			3	1		2			2			2			2		

B

V4-B2707-

INTERIORS DESIGN			DESIGN SUPPORT			PRODUCT SUPPORT			AERODYNAMICS STAFF			PROPULSION-MECHANICAL STAFF			STRUCTURES STAFF			ELECTRODYNAMICS STAFF			FLIGHT TEST			CUSTOMER ENGINEERING		
									3	1		3						3	1		3			1		
	1								1									3	1							
			3	1																						
						3	1																			
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			1			1			1			1			1			1								
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2			3	1		2			2			2			2			2								
2			3	1		2			2			2			2			2								
2			4			3	1		2			2			2			2								

Figure 5-5. (Concluded)

test program. Later, he will utilize developed procedures to demonstrate satisfactory compliance with many of the requirements.

The B-2707 air worthiness engineer, reporting to the chief engineer, is charged with specific tasks: (1) to review the airplane design with respect to air worthiness requirements, and (2) to assist in the development of air worthiness requirements.

5.2.7 Demonstration of Operational Integration
Demonstration of compliance with the operational integration requirements will be accomplished by one or more of the following means:

a. The outputs of the simulation program will be used extensively to verify the technical competence of many system elements as well as being used for establishing operational procedures.

b. The analysis, design, and successful development tests of many elements will be the demonstration of operational suitability.

c. Some of the tests included in the 100-hour flight program will verify critical integration factors.

d. Analysis of data from the 100-hour and follow-on prototype flight programs will be used to establish operational procedures for the B-2707.

e. Phase IV and V certification and production testing will give further satisfactory evidence of an operationally suitable airplane.

5.3 OPERATIONAL AIRPLANE PROGRAM
The goal of the operational integration program is to assure the timely, safe, and profitable assimilation of the B-2707 airplane into the world air transportation system and operating environments. This will be accomplished by planning and by using resources available to the company internally, within U.S. industry and within the FAA. Figure 5-6 shows the tasks and coordination required of the contractor, the FAA, the airlines and the airport operators for achievement of an operationally integrated B-2707.

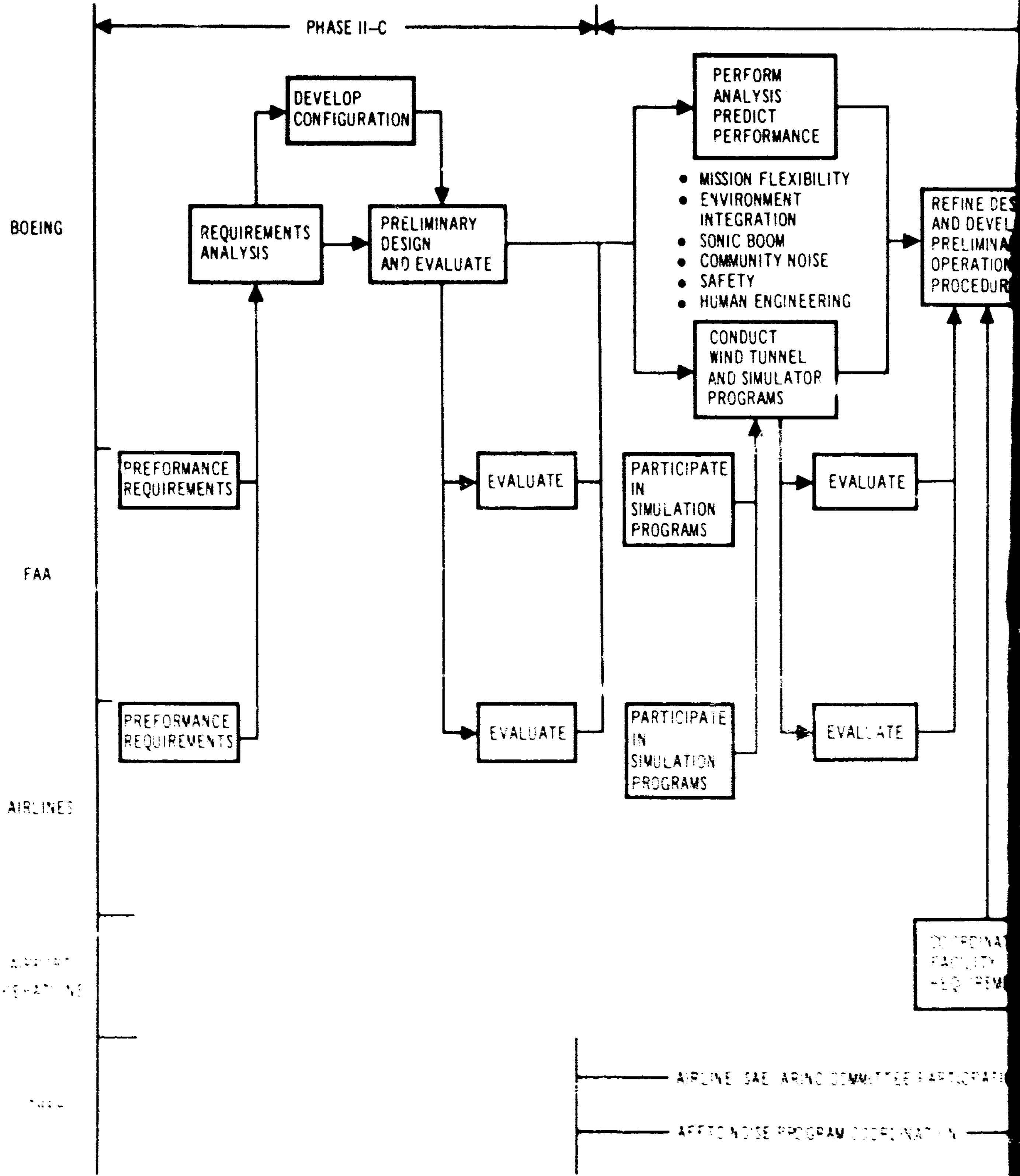
5.3.1 Mission Flexibility
Assurance of mission flexibility of the B-2707 airplane is one of the major goals of the operational integration program. Definition of mission flexibility as interpreted by the company is simply the continued safe and profitable commercial usage of the airplane within normal and off-design conditions and the safe usage of the airplane within abnormal and emergency operations. To achieve mission flexibility, operational analysis, wind tunnel programs and simulations will continue, operational procedures will be written, and the ground and flight tests programs will be conducted to provide a significant validation of the mission flexibility and suitability of the B-2707.

5.3.1.1 Flight Operations Procedures (Manuals)
Flight operations procedures will be derived for flight conditions and incorporated into a flight operations manual. An operational engineering group will be activated during Phase III to accomplish this task. Action will be taken to coordinate with FAA and the airlines to define flight standards, margins, and specific detailed operational requirements.

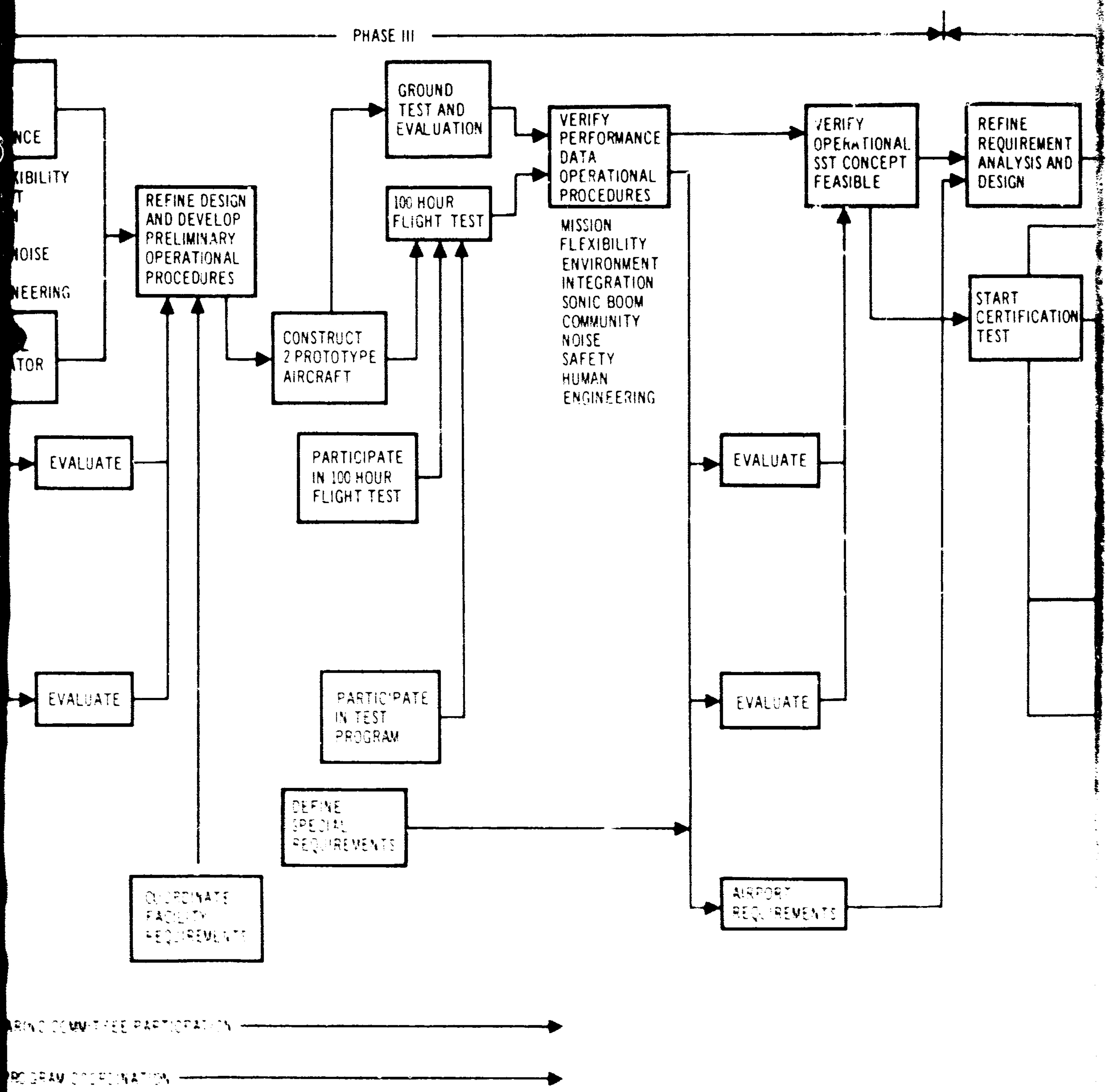
Also during Phase III, analyses of appropriate subsystems will be accomplished by design projects and the data thus derived will be used to develop flight operations, maintenance, and support procedures for the prototype airplane as shown in Fig. 5-7. Test, analyses, and simulation will be used to further define B-2707 flight characteristics and performance capabilities from which operating procedures for the prototype airplane will be developed early in Phase III. Normal, abnormal, and emergency procedures will be checked and validated using engineering simulators, mockups, and ground test equipment as the required items become available. The flight deck systems integration simulator (FDSIS) will be the primary means of validating operational procedures prior to first flight and for the development of prototype flight checklists.

During the 100-hour flight test program, sufficient test data will be acquired to refine flight operations manuals, instrument flight procedures, airport and community noise suppression, and sonic boom overpressure reduction techniques. Flight operations engineers will monitor prototype flight test operations, define improved operational procedures and become familiar with all aspects of B-2707 operations.

During Phase IV, the activities relating to the refinement of operational procedures will be continued using the B-2707 flight simulator and flight test program as a basis for the development of production aircraft operations manuals. The operational engineering group will coordinate procedural data with customer airlines and distribute airlines' inputs to appropriate engineering and flight test activities. In Phase V, flight operations manuals for individual airlines will be issued.



PHASE II–C
BOEING
FAA
AIRLINES
DEVELOP CONFIGURATION
REQUIREMENTS ANALYSIS
PRELIMINARY DESIGN AND EVALUATE
PERFORM ANALYSIS PREDICT PERFORMANCE
• MISSION FLEXIBILITY
• ENVIRONMENT INTEGRATION
• SONIC BOOM
• COMMUNITY NOISE
• SAFETY
• HUMAN ENGINEERING
CONDUCT WIND TUNNEL AND SIMULATOR PROGRAMS
PREFORMANCE REQUIREMENTS
PREFORMANCE REQUIREMENTS
EVALUATE
EVALUATE
PARTICIPATE IN SIMULATION PROGRAMS
PARTICIPATE IN SIMULATION PROGRAMS
EVALUATE
EVALUATE



PHASE III
GROUND TEST AND EVALUATION
VERIFY PERFORMANCE DATA OPERATIONAL PROCEDURES
VERIFY OPERATIONAL SST CONCEPT FEASIBLE
REFINE REQUIREMENT ANALYSIS AND DESIGN
REFINE DESIGN AND DEVELOP PRELIMINARY OPERATIONAL PROCEDURES
100 HOUR FLIGHT TEST
MISSION
FLEXIBILITY
ENVIRONMENT
INTEGRATION
SONIC BOOM
COMMUNITY
NOISE
SAFETY
HUMAN
ENGINEERING
CONSTRUCT 2 PROTOTYPE AIRCRAFT
START CERTIFICATION TEST
EVALUATE
PARTICIPATE IN 100 HOUR FLIGHT TEST
EVALUATE
EVALUATE
PARTICIPATE IN TEST PROGRAM
EVALUATE
DEFINE SPECIAL REQUIREMENTS
AIRPORT REQUIREMENTS

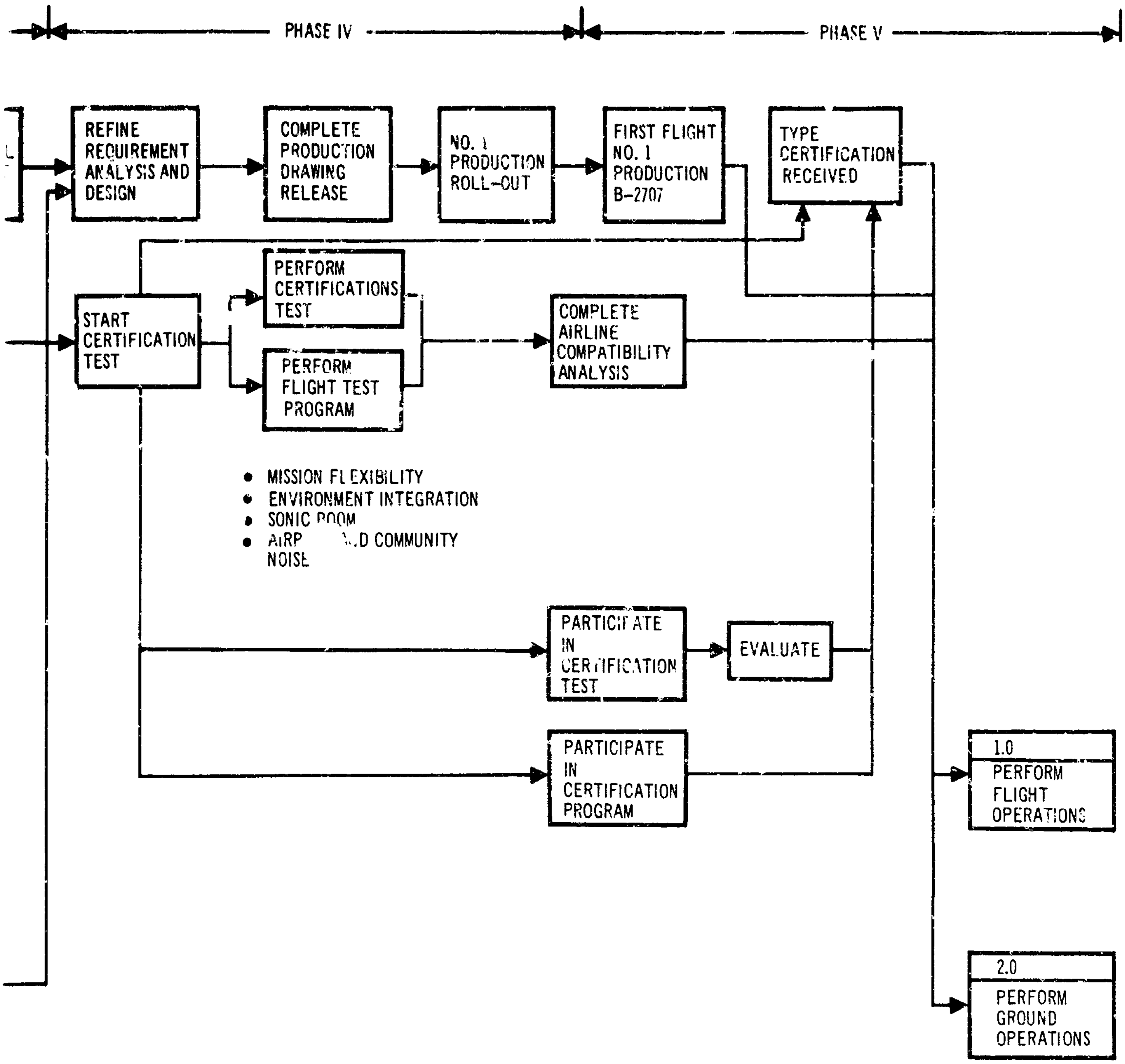
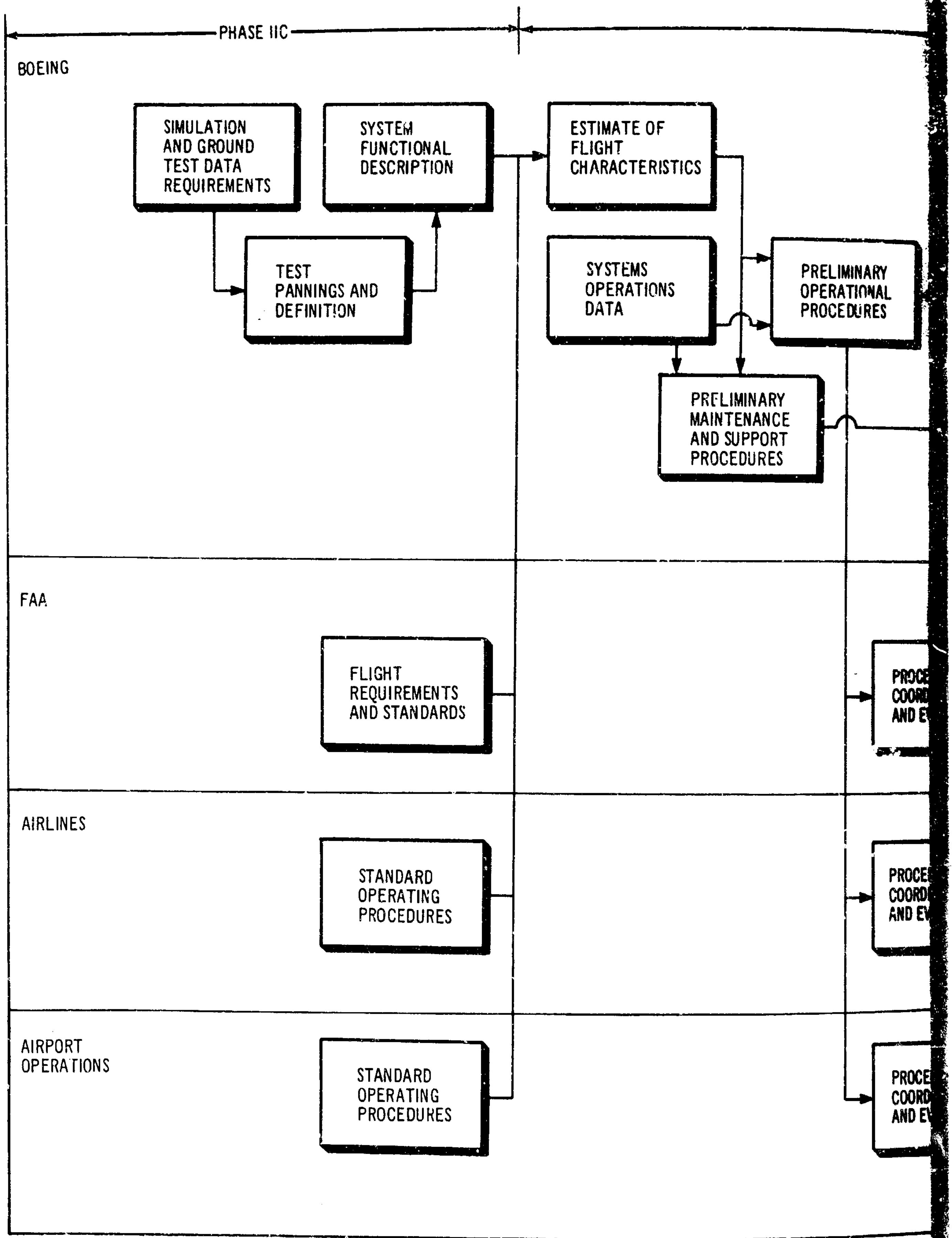
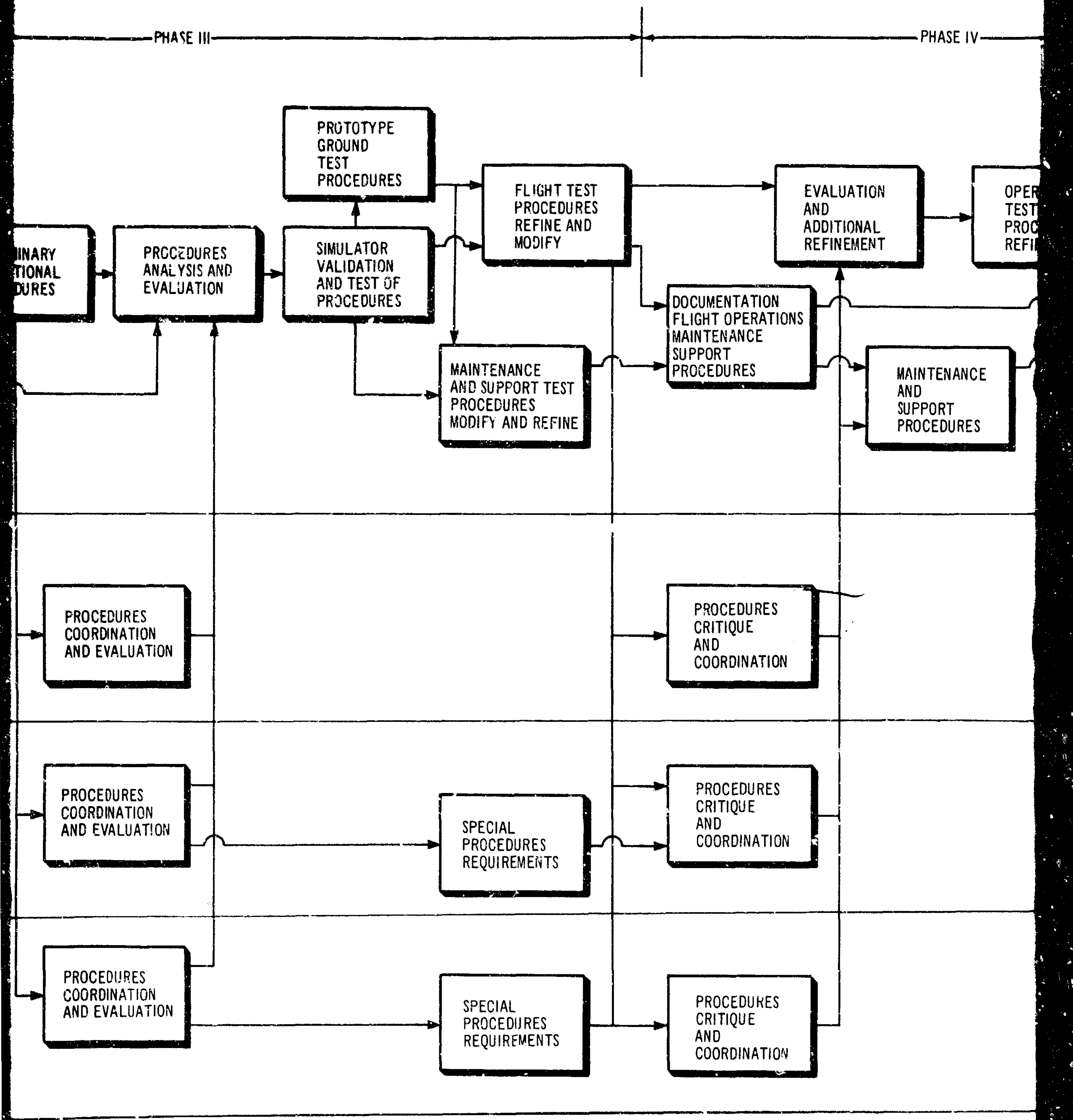


Figure 5-6. Operational Integration – Operational Airplane



PHASE IIC
BOEING
SIMULATION AND GROUND TEST DATA REQUIREMENTS
SYSTEM FUNCTIONAL DESCRIPTION
ESTIMATE OF FLIGHT CHARACTERISTICS
TEST PANNINGS AND DEFINITION
SYSTEMS OPERATIONS DATA
PRELIMINARY OPERATIONAL PROCEDURES
PRELIMINARY MAINTENANCE AND SUPPORT PROCEDURES
FAA
FLIGHT REQUIREMENTS AND STANDARDS
AIRLINES
STANDARD OPERATING PROCEDURES
AIRPORT OPERATIONS
STANDARD OPERATING PROCEDURES

4


PHASE III
PHASE IV
PROTOTYPE GROUND TEST PROCEDURES
FLIGHT TEST PROCEDURES REFINE AND MODIFY
EVALUATION AND ADDITIONAL REFINEMENT
OPER TEST PROC REFI
INARY TIONAL DURES
PROCEDURES ANALYSIS AND EVALUATION
SIMULATOR VALIDATION AND TEST OF PROCEDURES
DOCUMENTATION FLIGHT OPERATIONS MAINTENANCE SUPPORT PROCEDURES
MAINTENANCE AND SUPPORT TEST PROCEDURES MODIFY AND REFINE
MAINTENANCE AND SUPPORT PROCEDURES
PROCEDURES COORDINATION AND EVALUATION
PROCEDURES CRITIQUE AND COORDINATION
PROCEDURES COORDINATION AND EVALUATION
SPECIAL PROCEDURES REQUIREMENTS
PROCEDURES CRITIQUE AND COORDINATION
PROCEDURES COORDINATION AND EVALUATION
SPECIAL PROCEDURES REQUIREMENTS
PROCEDURES CRITIQUE AND COORDINATION

B

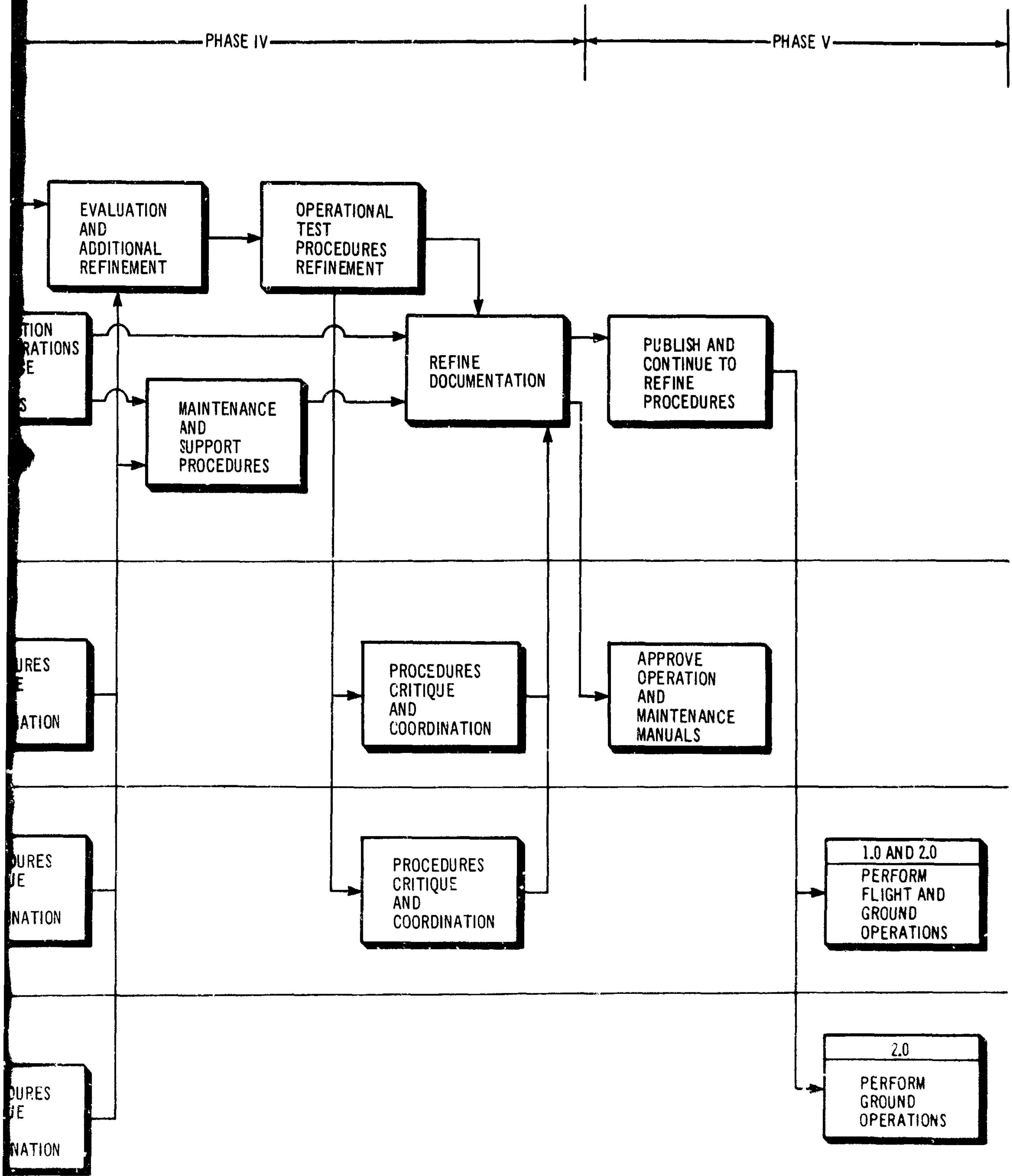


Figure 5-7. Operational Integration Procedures Development

5.3.1.2 Operational Data
Operational data will be developed during Phase III with which the procedures for normal, abnormal, and emergency conditions will be prepared as described in Par. 5.3.1.1. Abnormal and emergency conditions to be considered include off-design operations, midpoint emergencies and failures, three-engine ferry, all-weather landing, and engine-out conditions. In addition, the considerations of pilot visibility, crew workload, development of the minimum equipment list (MEL), and the duties of the project pilot are important factors in completing the operational data. Development of the operational data requires support from design, technical staff, and support groups.

Flight Characteristics - flight characteristics data is generated through analysis and wind tunnel testing for later use in simulation and subsequent flight testing. These data consist of the the following:

a. Airplane Performance

1. Determine aerodynamic parameters and derivatives to substantiate performance and stability levels of the airplane.

2. Determine takeoff and landing performance.

3. Determine off-design and emergency performance.

b. Stability, Control, and Handling Qualities

1. Determine overall aerodynamic stability and control characteristics and handling qualities throughout flight profile.

2. Conduct analyses and wind tunnel test to establish the static stability, dynamic stability, maneuvering stability, control response characteristics and handling qualities throughout the flight profile both for normal and reasonably probable emergency conditions. Flight characteristics both with and without the stability augmentation system in operation will be included.

3. Estimate the elastic airplane static and maneuver stability characteristics and control capabilities.

4. Provide rate, hinge-moment authority requirements for all primary and trim flight controls, and stability augmentation surfaces.

5. Determine critical flight characteristics (including emergency conditions) and their effects on other aspects of the total airplane performance.

Pilot Visibility - Pilot visibility continues to require study, evaluation and collection of operations data to assure mission flexibility. Continued development of visibility components will be accomplished during Phase III to refine the detail design and validate design changes if required. Visual flight simulation will be validated for normal landings, nose down and emergency landings.

In these tests, four or more speeds, four or more angles of attack, and true airplane dynamics will be employed in all cases.

Development changes and refinements will be evaluated in the field of optical qualifiers for: (1) light transmission, (2) glare, (3) multiple reflections, and (4) distortion and deviation. Existing optical studies mockup and facilities will be used as well as the Phase III lighted mockup.

Laboratory and flight tests will be continued during Phase III with television systems to:

a. Establish the phases of flight where television will be worthwile.

b. Investigate the potential of time-sharing or integration with other instrumentation.

c. Evaluate special purpose cameras and filters to determine the best combinations to cover the range of visibility conditions.

During the visibility studies, procedures for use of available pilot visibility or acquisition of visibility will be developed. The method of procedural development is as described in Par. 5.3.1.1.

Crew Workload--Crew workload studies, analysis and testing will be expanded in the Phase III B-2707 program to include effects of IFR opera-

tions, specifically Category III Instrument Landing and further examination of the following:

- Cruise management of the inertial navigation system
- Fuel management
- Pressurization management
- Normal operations of flight controls and hydraulic power
- Normal operation of wing sweep
- Normal operations of engine inlet hydraulic system

As these systems are further defined by engineering, additional tasks may be required to manage and operate them in flight and these will be incorporated into the task analysis.

In conjunction with the refinement of the normal operations, emergency procedures will be considered and will include, but not be limited to:

- Pressurization failure
- Air-conditioning pack failure
- Autopilot failure
- Generator failure
- Inlet hydraulic failure in which manual operation of the system is required
- Wing sweep failure
- Nose up or down failure

Consideration will be given to using computer analysis techniques as an aid in determining the tasks involved in emergency operations as well as some of the tasks involved in normal phases of flight.

Additional information on computer analysis techniques is presented in Human Engineering Program, V4-B2707-8.

The tasks outlined in the task analysis will be evaluated in Phase III by applying them in the training program to be conducted in the flight deck systems integrated simulator. The simulator environment is a step closer to actual test flying and, therefore, a higher degree of validity can be imparted to the tasks which prove applicable. The task analysis data will be updated by the results of this program.

Phase IV task and crew workload analysis effort will consist of making the final corrections to the study and generating the procedures for the operational B-2707. Some final corrections to the analysis may come as a result of possible engineering design changes; others, as a result of changes in flight operations and procedures which may be made during the flight test program. Again the procedural change will be as described in Par. 5.3.1.1.

Minimum Equipment List (MEL)--Minimum equipment list revisions during Phase III will be continued as significant data becomes available. Design trade studies, safety analyses, maintenance analyses, failure mode and effect analyses, and fault tree analyses will be reviewed and all changes will be evaluated for impact on the tentative MEL. Changes in the tentative MEL will be coordinated with and reviewed periodically with the project, concerned staff, and the pilots.

During flight test operations, the above groups will act in a review capacity and recommend modification of the tentative MEL. B-2707 flight test plan will be reviewed for procedures applicable to validation and verification of the tentative MEL. Applicable test results will be analyzed by a committee representing air-worthiness, system safety, reliability engineering, project and staff units, and the project pilot. Modifications of the tentative MEL will be based on the analysis of the flight test results by the committee.

The tentative MEL will be transmitted to the participating airlines for review and comment. Just prior to airplane certification, a review meeting will be convened by the B-2707 airworthiness group, with the Flight Operations Evaluation Board of the FAA and the participating airlines, to negotiate the MEL. Based upon the results of this meeting, the FAA will publish a final MEL for certification.

The MEL activity during Phase V will be limited to a follow-on effort. ECP's and production test data will be screened for possible impact on the MEL. Recommended changes will be forwarded to the FAA for appropriate action.

Project Pilot Responsibilities--Among the major responsibilities of the project pilot will be the gathering and dissemination of flight operations data. Other duties of the project pilot, flight test pilots and engineers include the following:

a. Assist in the experimental design of various simulation studies.

b. Participate in the simulation studies.

c. Discuss systems operation with the project and staff groups.

d. Maintain liaison and communication with FAA, Air Force, NASA, Navy, pilots and engineers involved in high-speed airplane, and simulator test programs.

e. Maintain liaison and communication with airline technical pilots and engineers relative to their needs and desires and new flight deck equipment proposals.

f. Continue to obtain, by direct contact, experience with present airline training and operating problems.

g. Promote and assist in the development of improved flight instrumentation and control equipment with an overall objective of increased operational safety.

h. Participate in the industry and Government discussions relative to certification and operations rules and regulations.

i. Follow, by direct participation, the continuing development of the subsonic airline equipment so that the B-2707 dovetails into an orderly progression of improvements. Particular emphasis is placed on the all-weather landing programs.

j. Maintain liaison with international SST developments through pilots and engineering personnel.

5.3.1.3 Demonstration and Compliance
The management approach discussion stated that compliance with integration requirements will be accomplished by one or more of several means. The most demonstrable of these are simulation and flight tests. Elements of the testing to verify operational integration are included in the Integrated Test Program, V4-B2707-11, the Flight Simulation Program, V4-B2707-13, and the Flight Test Program, V4-B2707-14.

One of the chief responsibilities of the project pilot will be to execute appropriate parts of these programs. The integration demonstrations are subject to management surveillance for purposes of verifying compliance as shown in Fig. 5-5.

5.3.2 Environment Integration
The activities required to assure compatibility of the B-2707 with atmospheric environment and the National Airspace System are described in the following sections. Supplementary descriptive material may be found in other substantiating data as shown by Fig. 5-8.

Demonstration of environment integration will be a major objective of the Phase III and IV programs. The demonstrations will be accomplished during Phases III and IV by analysis, simulation tests, prototype airplane flight tests, and the production airplane certification program.

The demonstration of the B-2707 system elements will verify that the airplane operates safely and satisfactorily in its atmospheric environment as specified in the model and subsystem specifications and operating manuals and is compatible with the National Airspace System. The plan for integrating the B-2707 airplane into its atmospheric environment is shown in Pars. 5.3.2.1 and 5.3.2.2. The integration program is not limited to elements of environment discussed in each section but is intended to indicate problem approach and proposed solutions by the company. However, the items discussed for integration are those which are currently of major concern to the FAA and the company.

5.3.2.1 Atmosphere

a. Turbulence. Digital and analog computer analysis also will be conducted during Phases III and IV to aid in establishing response characteristics for both loads and ride qualities as discussed in Airframe Design Report, Part C, V2-B2707-7. Existing programs dealing with turbulence will be monitored and results incorporated into the load and ride qualities of the B-2707. The structural integrity and airplane performance will be evaluated through the performance of specific tests, through data gathered during the course of the overall test program and from in-service experience. In Phase III, the prototype will be flown in turbulence to a very limited extent during the initial 100-hour test period. Emphasis during this period will be on performance, propulsion, and other necessary testing to the extent required

for demonstration of Mach 2.7 capability. The prototype will be extensively instrumented so that data will be gathered at all times in anticipation of unexpected encounters with clear air turbulence.

During Phase IV, confidence gained through demonstrated airplane handling qualities will permit deliberate seeking out of turbulence conditions as part of the overall flight test program.

During this period it is planned to conduct a comparative test on ride qualities by simultaneously exposing the B-2707 and 707 to the same turbulence environment. Also, during this period, measured gust loads and accelerations will be gathered as part of the dynamic gust loads survey discussed in the Airframe Design Report, Part C, V2-B2707-7. This testing will provide a high degree of confidence in the turbulence aspects of environmental integration. However, continued flight testing during Phases IV and V on all aspects of the total flight program will provide additional gust exposure in amounts normal to flight operational experience, which will contribute additional confidence and data. These later phases also will permit proving of advancements in ATC systems, weather and turbulence forecasting, and possible CAT detection systems.

b. Ozone. The effect of ozone on the B-2707 structure, and the establishment of safeguard measures and limits will be evaluated during laboratory, ground and flight tests during Phase III. Laboratory tests on materials selected for the B-2707 will be conducted during Phase III to prove their capability to withstand the concentrations of ozone expected in supersonic flight. These tests will provide the confidence required to then expose the prototype airplane to the actual environment.

Ozone removal effectiveness of the environmental control system will be evaluated in the one-quarter system laboratory test facility. The prototype will be instrumented to record the ozone levels and the length of exposure periods during the 100-hour flight test. Throughout these tests, it is planned to demonstrate that the ozone level on the B-2707 can be maintained below 0.2 ppm. The ozone concentration withint the pressurized area of the prototype will be measured to determine the effectiveness of the catalytic filtration of the environmental control system. The ozone concentration in unpressurized compartments such as the wheel well will be measured to maintain a close check of ozone effect on airplane materials at all times.

The data collected during the Phase III and Phase IV test activities will be reflected in the operating handbooks and training manuals. The demonstration that the B-2707 can successfully operate in an ozone environment will be a continuous process throughout the Phase III and Phase IV testing.

c. Radiation. Nonmetallic materials will be affected by solar ultraviolet radiation in the temperature and pressure environment of the supersonic flight altitudes. During Phase III, tests simulating the ultraviolet radiation found at 70,000 ft will be conducted to evaluate the effect of ultraviolet radiation on the exterior airplane surface materials. Results of these tests will be correlated with actual flight data obtained during Phase IV and Phase V and evaluated for their impact on airplane surface design, operating handbooks, and training manuals.

During severe solar flare events, radiation levels at high cruise altitude may exceed tolerance levels for crew and passengers. Data from FAA sponsored flight tests will be used to aid in establishing detection requirements. Boeing will monitor solar flare programs to develop operating procedures to contend with solar flare occurrences.

d. Particulate Matter. Available data on aerosol particulate matter concentrations of flight altitudes for supersonic aircraft indicate that no erosion or chemical attack to the surface of the aircraft should occur from this source. To verify this conclusion, surfaces will be inspected for evidence of surface degradation due to the impact of particulate matter after each prototype flight during Phase III.

The natural aerosol particles of the stratosphere can collect radioactive debris released into the atmosphere from nuclear explosions. During Phase III flight tests, the cabin and air-conditioning system will be monitored for radioactive particles to evaluate the inherent filtration capabilities of the air-conditioning system.

Exterior surfaces of the airplane will be monitored for radioactive contamination and will be washed to decontaminate them as necessary.

ELEMENTS OF ATMOSPHERIC INTEGRATION \ PHASE IIC REPORT VOLUME	SYSTEM ENGINEERING REPORT V2B2707-1	MOCKUP PLAN V2B2707-2	AERODYNAMIC DESIGN REPORT V2B2707-3	AIRFRAME DESIGN REPORT PART C V2B2707-7	AIRFRAME DESIGN REPORT PART D V2-B2707-8	SYSTEMS REPORT PART A V2-B2707-10	SYSTEMS REPORT PART B V2-B2707-11	PROPULSION REPORT PART B V2-B2707-13	B-2707 MODEL SPECIFICATION D6-17850	TRAINING EQUIPMENT SPECIFICATION D6A10181-1	TECHNICAL PUBLICATIONS SPECIFICATIONS
TURBULENCE	X		X	X	X		X		X	X	X
OZONE	X				X	X	X		X		
RADIATION	X				X	X	X		X		
PARTICULATE MATTER	X			X	X	X		X	X		
AIR TRAFFIC CONTROL	X		X			X			X	X	
COMMUNICATIONS	X	X				X			X	X	
NAVIGATION	X	X				X	X		X	X	

A

SPECIFICATIONS							X
PROPULSION REPORT PART B V2-B2707-13				X			
B-2707 MODEL SPECIFICATION D6-17850	X	X	X	X	X	X	X
TRAINING EQUIPMENT SPECIFICATION D6A10181-1	X	X	X				X
TECHNICAL PUBLICATIONS SPECIFICATIONS D6A19182-1	X	X	X				X
OPERATIONAL SUITABILITY V4-B2707-1	X	X	X	X	X	X	X
SYSTEM SAFETY PLAN V4-B2707-6				X	X	X	X
TRAINING AND TRAINING EQUIPMENT PROGRAM V4-B2707-7	X	X	X				X
HUMAN ENGINEERING PROGRAM V4-B2707-8	X	X	X	X	X	X	X
INTEGRATED TEST PROGRAM V4-B2707-11	X	X	X	X		X	X
FLIGHT SIMULATION PROGRAM V4-B2707-13							X
FLIGHT TEST PROGRAM V4-B2707-14	X	X					X
ECONOMIC SUMMARY V7-B2707-1				X	X	X	

Figure 5-8. Environment Integration Reference Index

Particulate matter filters for the air-conditioning system will be developed during Phase III to protect the crew and passengers if required.

5.3.2.2 National Airspace Compatibility
The selection of the communications and navigation equipment will be evaluated for its responsiveness to present ATC requirements and for its capability to meet future ATC requirements.

Compliance with present requirements will be demonstrated through laboratory, ground, and flight tests of the following equipment:

- VHF communications
- HF communications
- ATC transponder
- Inertial navigation systems
- Automatic direction finder
- VORTAC
- Instrument landing system
- Weather radar
- All-weather landing

The design and performance of the communications and navigation equipment will be verified during Phase III. Bench tests will be conducted to verify that the individual design and performance characteristics meet their respective design requirements. Integration tests will then be conducted to verify that these subsystems will interface properly with other comm/nav equipment with no electromagnetic interference.

During the airplane ground tests, the communication and navigation equipment will be tested to assure that they can operate properly in the airplane environment. The equipment will then be flight tested and evaluated. The tests will be conducted using the operating handbooks thus, guaranteeing that they can in fact be used in service.

During Phase IV and V, continued coordination with ATC will be maintained to evaluate new communication/navigation equipment requirements. VHF communication test procedures will be modified with the advent of time sharing data link to verify the VHF transceiver capability to adopt time sharing data link. The need for HF communications will be reviewed with respect to the proposed satellite communications and ocean based communications in view of the fact that these systems will be operated on the United States to Hawaii/Alaska routes.

5.3.3 Sonic Boom and Community Noise
The sonic boom and community noise studies and analysis which were begun in detail in Phase II of the B-2707 program will be continued in Phase III. The program started in Phase II-C will be substantially expanded with the addition of empirical data from the XB-70 and other experimental high-speed flight programs, plus measurements taken when possible from B-2707 flight tests. In particular, the effect of maneuvers will be closely examined and the company will work closely with NASA Langley on sonic boom studies. The sonic boom characteristics program, discussed in detail in V4-B2707-3, will be coordinated with the mission profile, flight operations procedures and navigation techniques available with I-NAV system to minimize the operational impact of sonic boom.

Integration of the B-2707 airplane into the "airport community" is also a determinate of the mission flexibility of the airplane. Both the GE and P&WA engines were studies during Phase II. However, study, analysis and test of Phase III on airport and community noise will be limited to the source selection engine. Characteristics of noise will be examined during takeoff, departure, landing approach, ground operations and maintenance in conjunction with the flexibility in operating procedures provided for the B-2707. Details of the community and airport noise problem are discussed in the Airport and Community Noise Program V4-B2707-4.

5.3.4 Safety
The superior safety attributes of the B-2707 airplane as described in System Safety Plan V4-B2707-6, are fundamentally dependent upon three actions, particularly during Phase III. These are:

a. The identification of hazards to which the airplane may be exposed.

b. The incorporation of design features which eliminate or compensate for such hazards.

c. A broad program of design review and testing which verify that these hazards have been identified and rectified.

Within the broad framework of the objective of the B-2707 safety program, provisions are made for elimination of all logical potential material and human errors which may produce injury or damage causing events. The safety objective will be realized when no item of safety is compromised to achieve any other program objective in design, test or integration.

During Phase IV, changes in prototype design made to accomplish a production configuration will be evaluated using the same safety analysis and review techniques established for earlier phases. Operational safety analysis will be completed prior to airplane certification for customer use. An expanded program of airline coordination will be accomplished during Phase IV to assure that no operating conditions or methods peculiar to an airline usage will compromise airplane safety.

During Phase V, airline support plans will be implemented and operational data analysis performed to determine possible safety improvements. Proposed design changes will be reviewed for safety implications as proposed in previous phases.

5.3.5 Human Engineering
The work tasks and reporting to be accomplished during Phase III prototype development are presented in detail in the Human Engineering Program, V4-B2707-8.

Program activity is divided into three major areas:

- Analysis
- Design support
- Test and evaluation

Primary tasks defined for these areas are as follows:

a. Participate in the systems analysis by accomplishing detailed task, timeline and workload analyses of flight crew functions for both normal and selected emergency operations.

b. Review and provide inputs to the maintenance analysis (personnel tasks and task times).

c. Define human performance capability, actions, and response times for the fault-tree analysis and the failure/error mode, effect, and criticality analysis.

d. Determine detailed display and control requirements for systems equipment.

e. Determine the basic display and control characteristics required to define functional alternatives (individual, integrated or time-shared displays and controls) and assist in accomplishing design approach trades based on frequency of use, association of use, and convenience of use; as well as weight, power, volume, and cost data.

f. Provide human engineering criteria for detailed equipment design, workspace layouts, procedures, and facilities associated with system functions requiring human performance.

g. Prepare and implement a Human Engineering/Life Support Test and Evaluation Program to assess human performance and man/equipment compatibility. The program will include mockup evaluations and participation in planning and conducting man-in-the-loop simulation tests, as well as analyzing the results.

h. Accomplish informal design reviews and participate in critical design reviews (CDR).

i. Ensure human engineering review of design changes through use of configuration change board and drawing release systems.

j. Monitor, control, and specify requirements for subcontractor human engineering activity where there is a design commitment for equipment used by system personnel.

k. Use a corrective action system for followup and resolution of human performance problems identified in hardware or design reviews.

l. Provide periodic progress reports of the work accomplished. Revise and update the program plan as required.

The Phase IV activity will essentially evaluate changes in personnel activities that result from the changeover to a production design from that of the prototype airplane. The human engineering task will verify compatibility of GSE with personnel, completeness of task procedures, performance times, and skill requirements. Phase IV certification will also provide identification of problem areas and a basis for corrective action in the B-2707 production configuration.

Phase V human engineering activities will be limited to the review and investigation of reports of problems of full commercial operations. Support will be provided to resolve personnel/equipment in-service problems which arise from these operations. Special support will also be

provided during Phase V when requested by the customer for modifications to the airplane to add equipment for provisions for passengers, crew or maintenance personnel.

5.4 GROUND HANDLING AND SUPPORT PROGRAM

To ensure proper integration of ground handling and support requirements into the prototype and production airplane programs, an active product support program will be initiated concurrently with the design and manufacture of the B-2707. The varied elements of product support which contribute to the safe and economical operation and maintenance of the B-2707 throughout its operational life are discussed fully in the Product Support Program, V4-B2707-20. Pertinent to ground handling and support, the Product Support Program discusses the Airline Contact Plan, the Ground Support Equipment Plan, the Training and Training Equipment Plan, the Data and Handbooks Plan, the Spares Support Plan, the Post-Delivery Support Plan, and the manner in which these elements are functionally integrated. The areas of primary interest are the Ground Support Equipment Plan and the aspects of other Product Support elements dealing with maintenance planning. Scope of the activity is shown in Fig. 5-9.

5.4.1 Ground Handling and Support Requirements

For Phase III, the Boeing ground support program plan is to utilize airline type ground support equipment for all necessary prototype ground operations and maintenance requirements as identified by requirements analysis. The requirements analysis initiated in the preliminary design phase to define ground support requirements will be continuously iterated throughout the Phase III, IV, and V program to evaluate configuration refinements and to establish current airplane and engine ground handling, servicing, and maintenance requirements. This analysis is conducted jointly by the design support and product support sections, who work closely with the airplane design project, customer engineering, and systems test organizations to achieve prompt revision action in response to changing requirements.

Analysis and evaluation of GSE requirements and in-service use will be continued throughout the production program to support modifications or differences in airline configurations, and to incorporate advanced design

5.4.2 Support Procedures

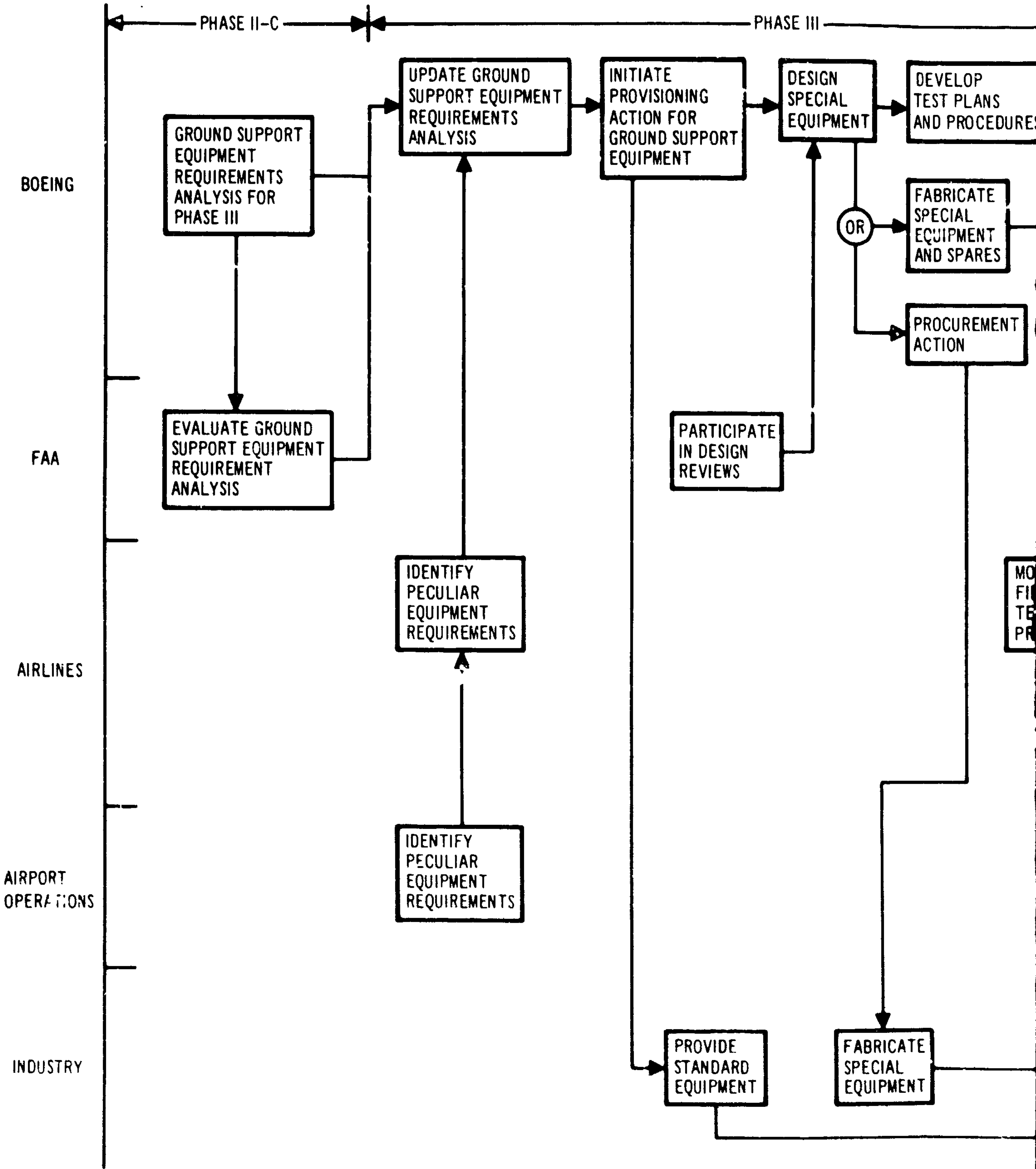
During Phase III, B-2707 operations will be analyzed and ground support procedures will be tested, validated, and refined during the ground and flight test programs. Liaison will be maintained with airlines and airport operators, and during Phases IV and V specific requirements of each airline customer and associated airport operator will be defined. The contractor will assist each customer and their respective servicing organization in adapting support procedures, developed in Phase III, to their peculiar requirements.

5.4.3 Ground Support Equipment

Whenever possible, ground support equipment (GSE) requirements will be satisfied by using available contractor equipment or standard, qualified, commercial or Government GSE. Special GSE will be designed by the GSE engineering organization to satisfy requirements for which standard GSE is unavailable. To ensure that ground support equipment used during the prototype development program is evaluated in the configuration to be used by airlines, continuous configuration control will be maintained. Special GSE will be developed concurrently with the prototype airplane and integrated into the manufacturing and test programs to support the prototype airplanes and check out design adequacy and compatibility. Throughout the prototype flight test program, ground handling and service operations and GSE will be evaluated in accordance with formal test plans (Ref. Integrated Test Program, V4-B2707-11) to ensure that operations time objectives are being met and that operational integration will be satisfactorily achieved.

5.4.4 Airline Coordination

During all phases of development, the Company will establish and maintain effective liaison with the world's airlines to support their planning for B-2707 ground operations and to enlist their guidance. Boeing will provide a Ground Support Equipment and Operational Facilities Planning Guide, similar to those provided for subsonic airplane programs. This document will reflect Boeing's ground support experience with the B-2707 prototype airplane. Customers will also be provided with the GSE Requirements Specification, D6A10180-1 which includes identification and technical data on all standard and special GSE required for the B-2707. GSE performance specifications and detail design drawings for special GSE will also be made available.


PHASE II–C
PHASE III
BOEING
FAA
AIRLINES
AIRPORT OPERATIONS
INDUSTRY
GROUND SUPPORT EQUIPMENT REQUIREMENTS ANALYSIS FOR PHASE III
EVALUATE GROUND SUPPORT EQUIPMENT REQUIREMENT ANALYSIS
UPDATE GROUND SUPPORT EQUIPMENT REQUIREMENTS ANALYSIS
IDENTIFY PECULIAR EQUIPMENT REQUIREMENTS
IDENTIFY PECULIAR EQUIPMENT REQUIREMENTS
INITIATE PROVISIONING ACTION FOR GROUND SUPPORT EQUIPMENT
DESIGN SPECIAL EQUIPMENT
PARTICIPATE IN DESIGN REVIEWS
DEVELOP TEST PLANS AND PROCEDURES
OR
FABRICATE SPECIAL EQUIPMENT AND SPARES
PROCUREMENT ACTION
PROVIDE STANDARD EQUIPMENT
FABRICATE SPECIAL EQUIPMENT

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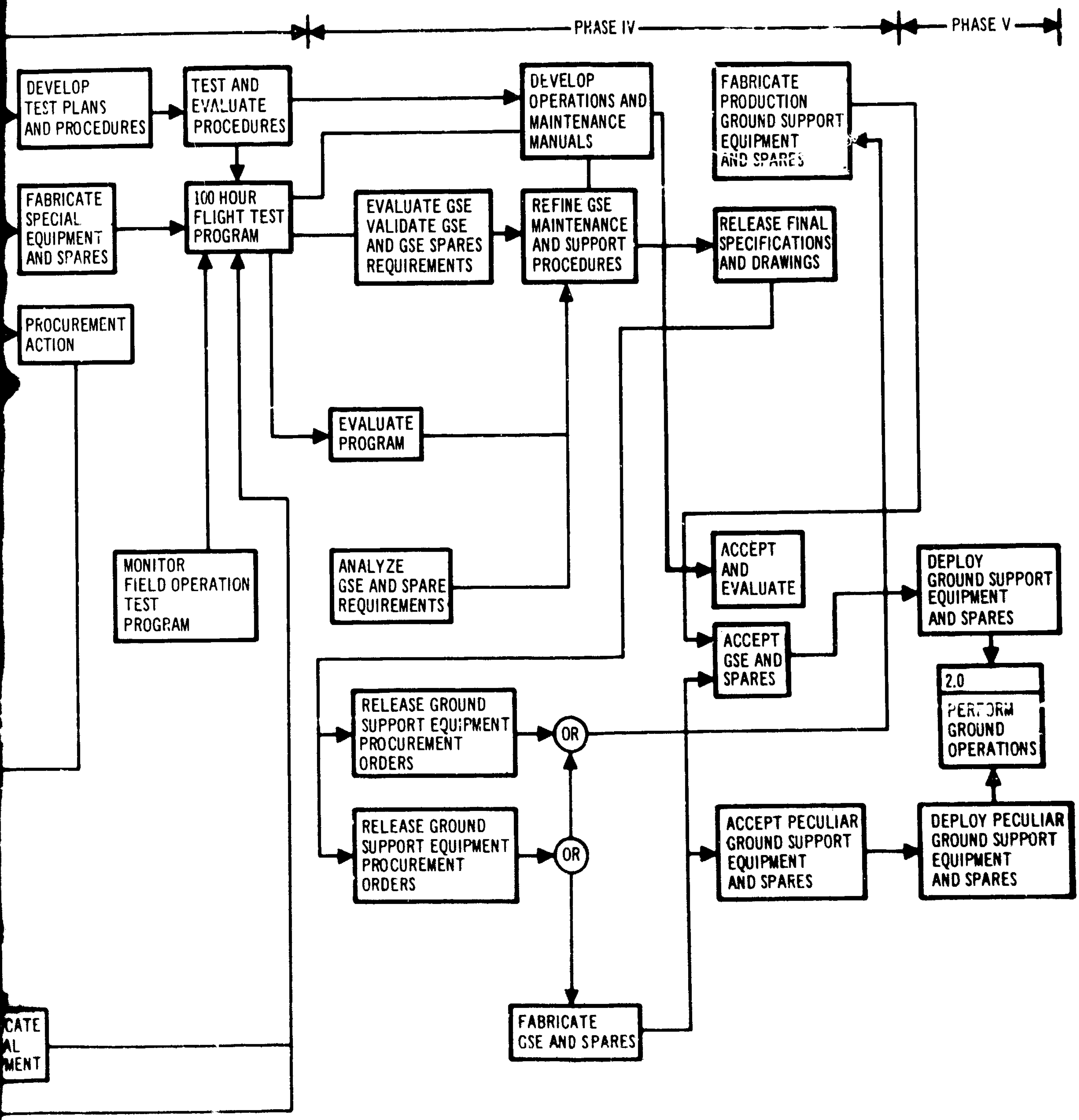


Figure 5-9. Operational Integration Ground Handling and Support Activities

5.4.5 Maintenance
Integration of the maintenance activities with the B-2707 prototype and production program involves determination of (1) maintenance requirements, (2) maintenance timing, and (3) maintenance procedures. Requirements and timing are specified in the Maintenance Planning Data document. Development of this document is discussed in Sec. 7.0 (Post-Delivery Support Plan) of the Product Support Program, V4-B2707-20. Procedures are described in Sec. 5.0 of the same document. Figure 5-7 shows the overall procedures program. During Phases III and IV, the prototype airplanes will be maintained basically in accordance with the preliminary maintenance plan, and the maintenance procedures identified in the prototype Maintenance Manual will be verified. The maintenance manual will be updated for the production airplane program. During Phase IV, discussions will be held with the airlines to formulate a final airline maintenance plan, which will be presented by the airlines to the FAA Maintenance Review Board for approval.

5.5 AIRPORT SUITABILITY – AIRLINE FACILITIES

5.5.1 Introduction
Introduction of new airplanes into service on the world's airways has historically necessitated modifications to the operational facilities supporting these aircraft. Lack of an adequate assessment of new requirements and the requisite planning has resulted in certain operational hardships as well as crash construction programs to meet the new needs. In order to preclude a recurrence of this and to assure the successful integration of the B-2707 with the operational facilities, a suitability evaluation program was initiated at the outset of the SST development competition. This evaluation has continued through Phase II-C, and is limited to 15 domestic airports to evaluate comparative impact of two competing designs.

5.5.1.1 Objective
The objective of this plan is to present a comprehensive course of action to assure the successful integration of the B-2707 with the world's airports and airline facilities which form a part of its ground environment.

5.5.1.2 Scope
The scope of the Phase II-C evaluation program will be expanded during Phase III and subsequent phases to include the time-phased acquisition of the B-2707 by the world's major airlines and their sequenced introduction to the world's airways and airports. The scope will be broadened to include airline maintenance, overhaul, training and other support facilities, in addition to the airport facilities. These evaluations will form the technical basis for an economic analysis of investment requirements by Government agencies and airlines. In addition, the plan presents the methods to be used in allocating facility investment costs among the new airplanes to determine Government and airline investment requirements.

5.5.1.3 Approach
The integration process is primarily a continuous evaluation process to:

a. Determine the B-2707 requirements which are beyond the capability of airline and airport facilities projected to be available at the time of B-2707 introduction into service.

b. Provide the results of the evaluations to the airplane design project for consideration of design changes which will mitigate new requirements.

c. Document and coordinate the remaining requirements with the Government agency or airline responsible for provisioning the facilities.

d. Provide to the provisioning agency or organization such additional data and engineering support as may be required to successfully implement remedial planning.

5.5.2 Management Interfaces
The Airport Suitability – Airline Facility Program management interfaces are shown on Fig. 5-10. The SST program office of the FAA, will provide the basic guidance for the conduct of the program as well as evaluation of progress and contract performance. The individual airlines and the airline supersonic transport committee provide program direction and guidance through definition of their respective requirements and evaluation of performance and progress. The airport operators provide the airport data used in the suitability evaluations. The results of these evaluations are then considered in the airport master planning.

The contractors management of the airport suitability program is an integral part of the total program management, and consequently will use the same visibility and control techniques as defined in Cost and Schedules Control Program, V5-B2707-6.

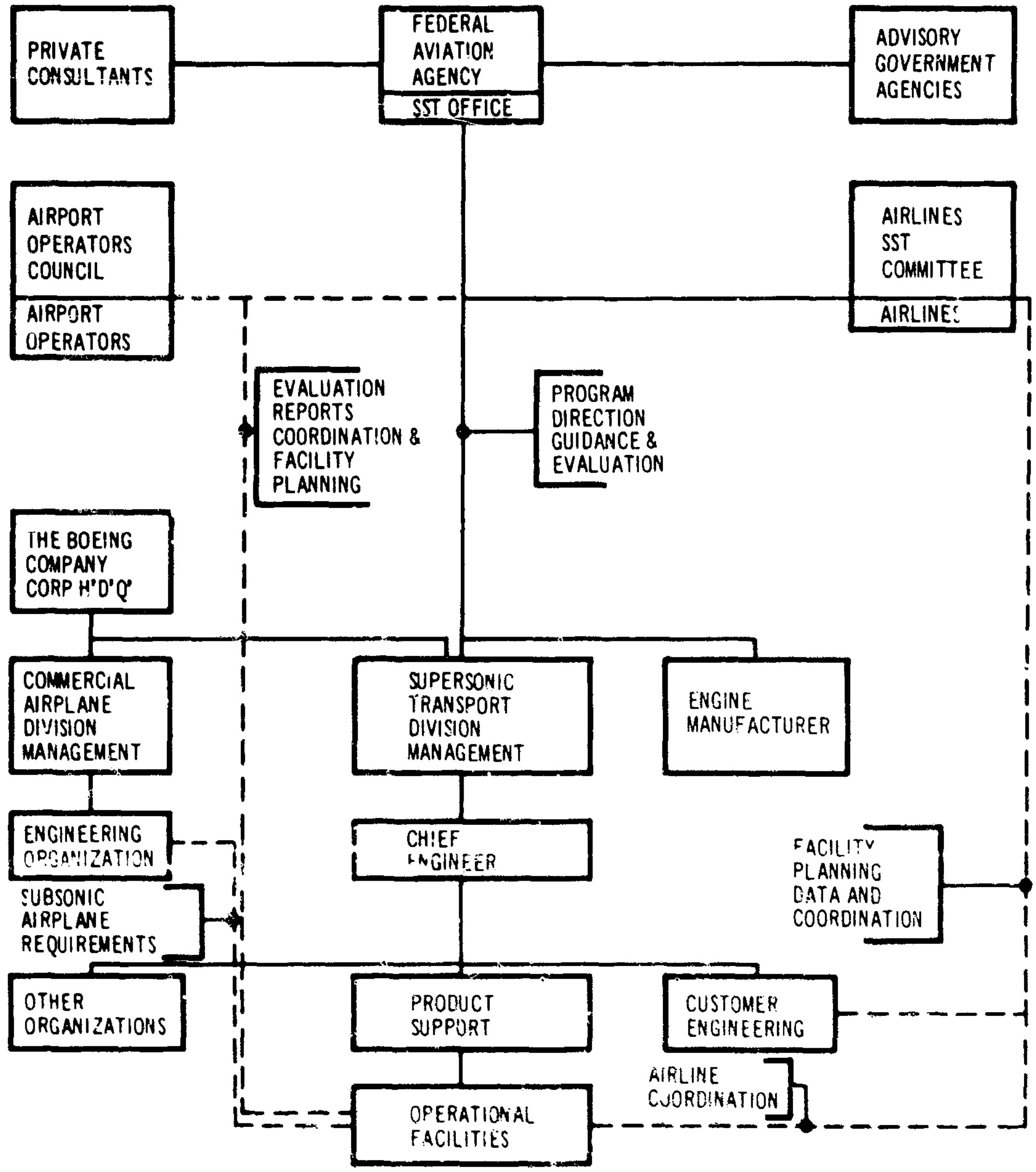


Figure 5-10. Airport Suitability—Airline Facility Program Management Interfaces

The program tasks and functions as described in this plan will be carried out by the operational facilities unit within the product support section of the engineering department. The distribution of functions within this organization are shown on Fig. 5-11. The total organizational tasks are separated according to functions related to: (1) airport suitability, (2) planning, and (3) airline facilities. This organization is the focal point for SST division coordination with the airport operators.

Figure 5-12 is a schematic diagram, of the Airport Suitability - Airline Facilities Program. It shows the sequence of events leading to successful integration of the B-2707 with its operational facilities environment.

5.5.3 Requirements

The suitability of a given airport is a function of the airport configuration and capability, and total requirements imposed on the airport. These requirements include airplane traffic volume,

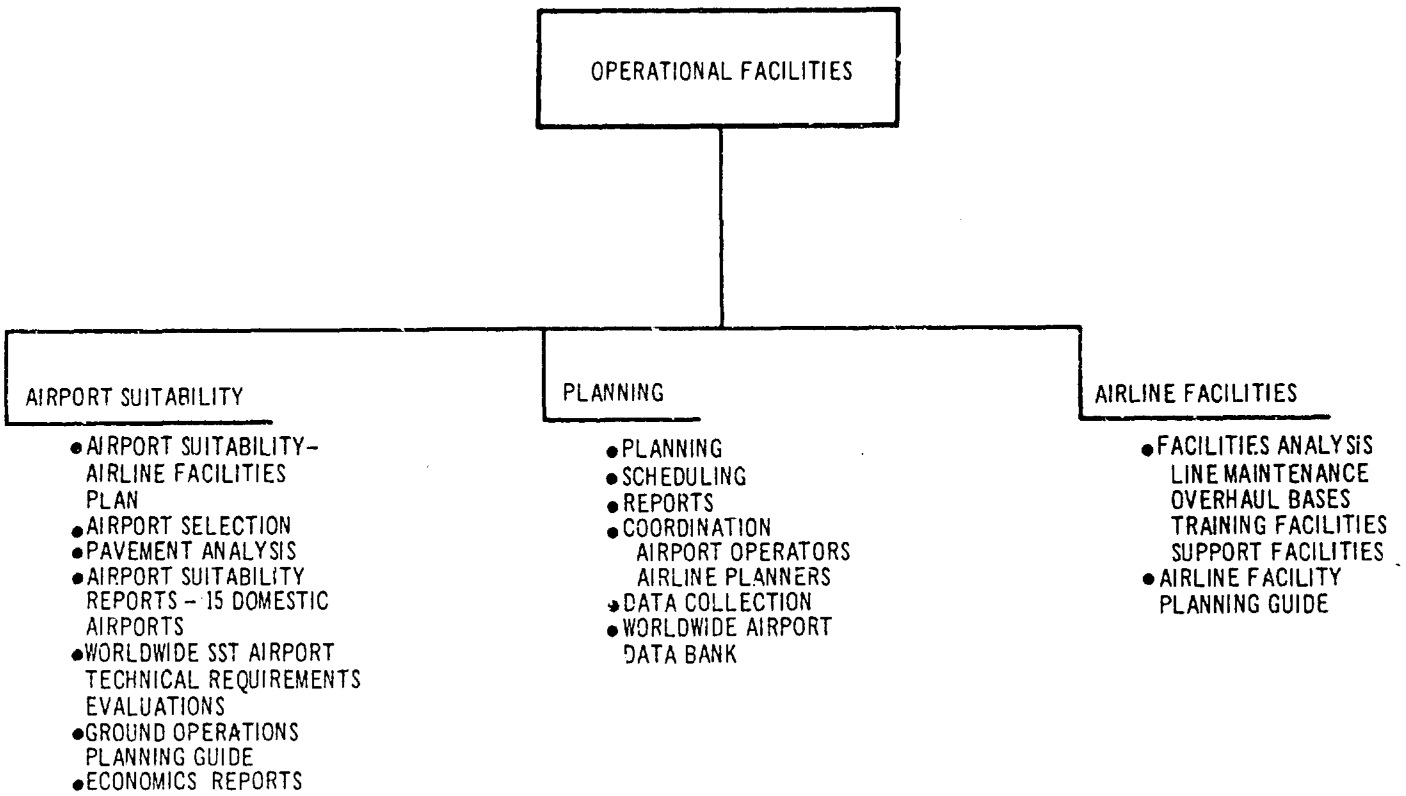


Figure 5-11. Organizational Functions

passenger volume, FAA requirements and recommended criteria, and requirements imposed by airlines, airport operators, and local governments. The type and configuration of airplanes handled as well as the ground systems equipment are also part of the total requirements.

5.5.3.1 FAA Requirements

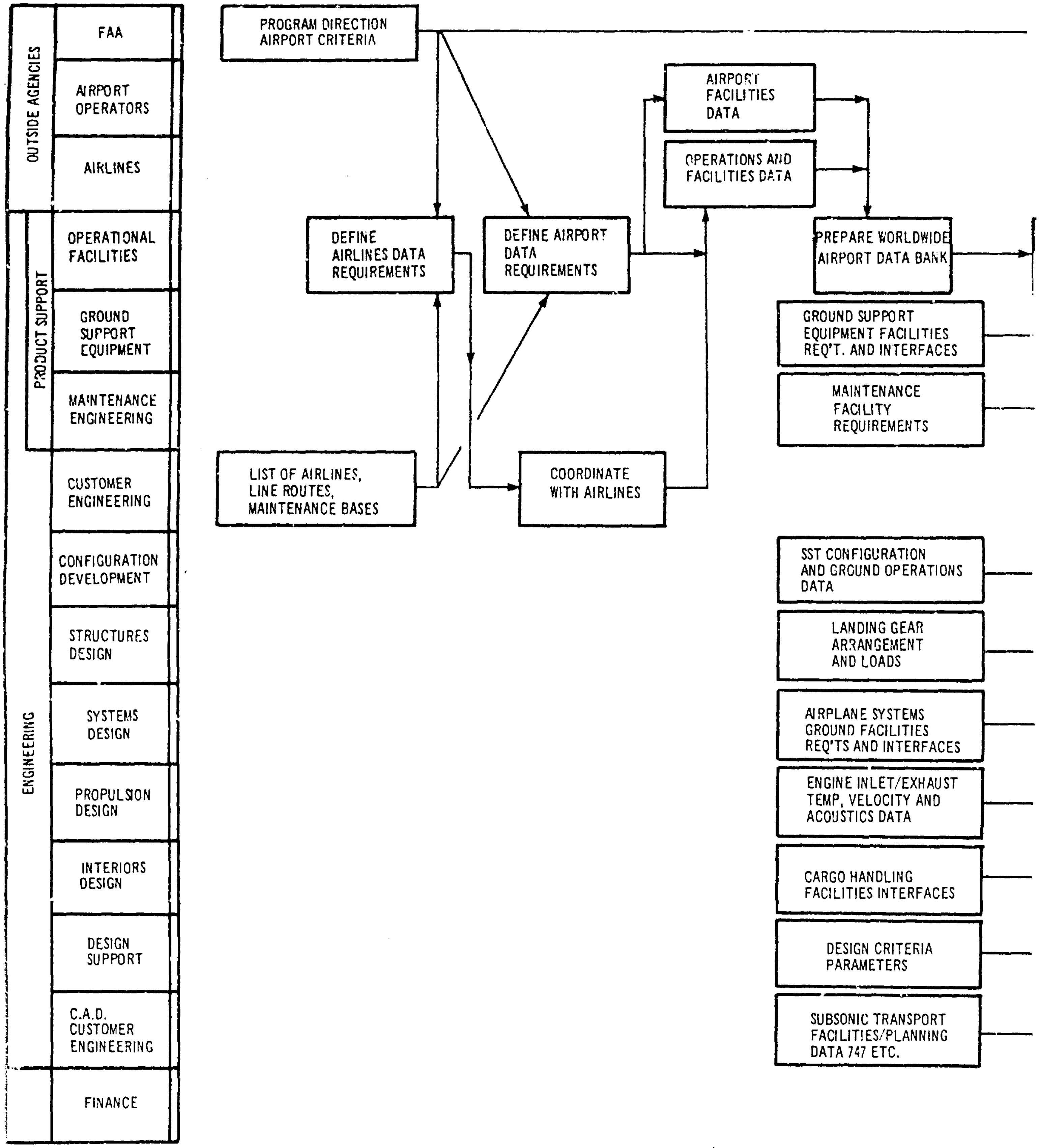
There are those recommended standards and criteria related to facilities and airports which are defined by the appropriate bureau and division within the FAA. These criteria, as they affect pavement strength and geometry, clearances, safety, passenger and cargo/baggage handling, and other fixed and mobile facilities will be used as minimum standards to define the modifications necessary to support the B-2707. These criteria are presented in FAA publications, including the advisory circulars.

5.5.3.2 Airport Operators Requirements

While the FAA provides facility criteria which are acceptable for projects of the Federal-aid Airport program, the airport operators as the provisioning agency have requirements regarding their facilities which may be different from this criteria. This condition may arise as a result of state or local construction requirements or some unique constraints imposed by a particular airport's location or mode of operation. This type of condition is most readily apparent with respect to non-U. S. airports. In these cases it will be necessary to evaluate local government regulations as well as airport operator requirements.

Since most of today's airports are in a process of continuing modernization to meet current and anticipated traffic, the current capability and projected plans are in a constant state of change. As a result, it is essential to include the projected airport plans in the evaluation.

General requirements of the airport operators will become apparent through the airport operator council participation; however, the individual


OUTSIDE AGENCIES
FAA
AIRPORT OPERATORS
AIRLINES
PRODUCT SUPPORT
OPERATIONAL FACILITIES
GROUND SUPPORT EQUIPMENT
MAINTENANCE ENGINEERING
ENGINEERING
CUSTOMER ENGINEERING
CONFIGURATION DEVELOPMENT
STRUCTURES DESIGN
SYSTEMS DESIGN
PROPULSION DESIGN
INTERIORS DESIGN
DESIGN SUPPORT
C.A.D. CUSTOMER ENGINEERING
FINANCE
PROGRAM DIRECTION AIRPORT CRITERIA
DEFINE AIRLINES DATA REQUIREMENTS
DEFINE AIRPORT DATA REQUIREMENTS
AIRPORT FACILITIES DATA
OPERATIONS AND FACILITIES DATA
PREPARE WORLDWIDE AIRPORT DATA BANK
LIST OF AIRLINES, LINE ROUTES, MAINTENANCE BASES
COORDINATE WITH AIRLINES
GROUND SUPPORT EQUIPMENT FACILITIES REQ'T. AND INTERFACES
MAINTENANCE FACILITY REQUIREMENTS
SST CONFIGURATION AND GROUND OPERATIONS DATA
LANDING GEAR ARRANGEMENT AND LOADS
AIRPLANE SYSTEMS GROUND FACILITIES REQ'TS AND INTERFACES
ENGINE INLET/EXHAUST TEMP, VELOCITY AND ACOUSTICS DATA
CARGO HANDLING FACILITIES INTERFACES
DESIGN CRITERIA PARAMETERS
SUBSONIC TRANSPORT FACILITIES/PLANNING DATA 747 ETC.

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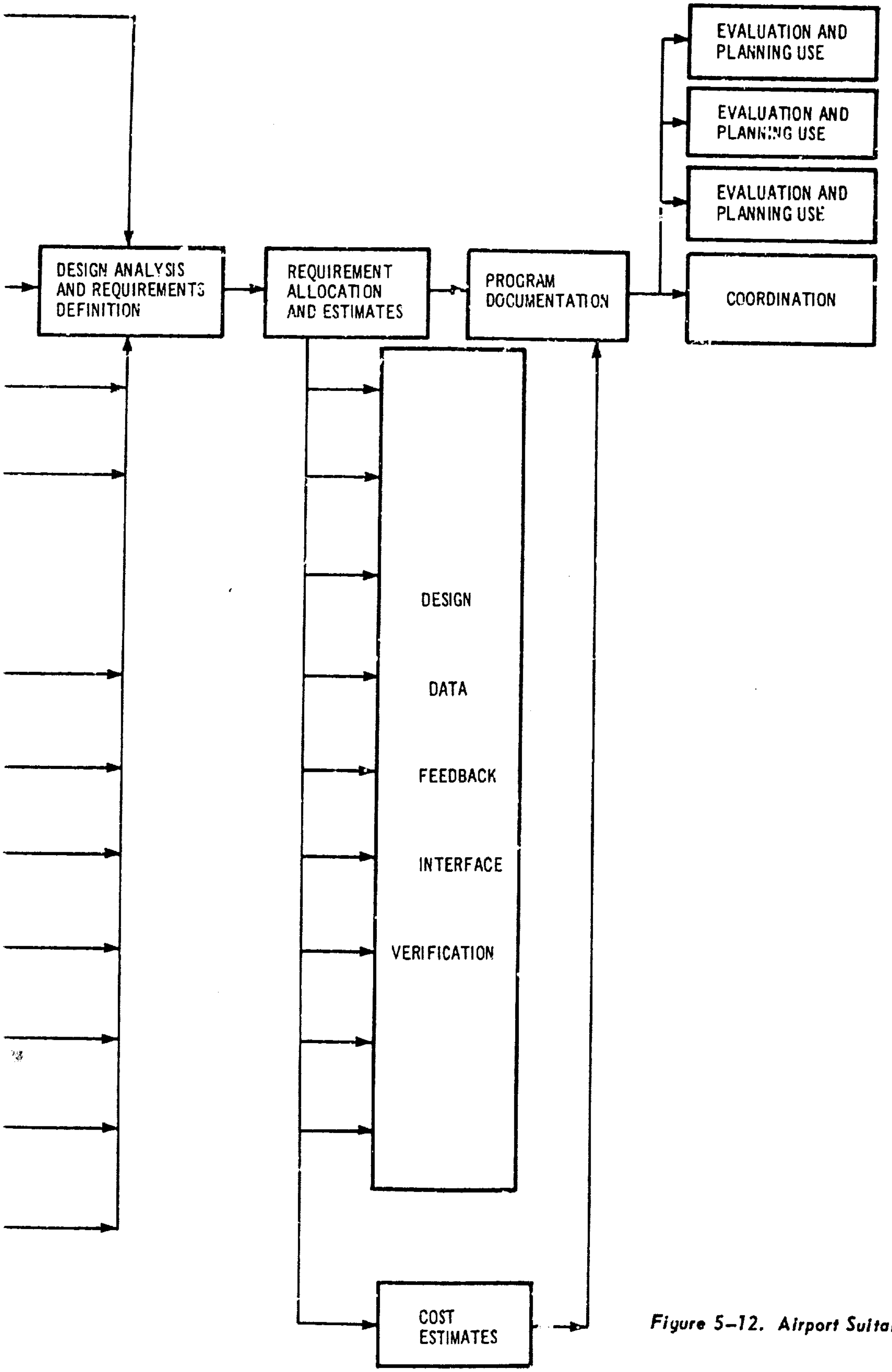


Figure 5–12. Airport Suitability – Airline Fa...

airport operators specific requirements will flow to the contractor through direct contact at the time of data collection and evaluation report coordination.

5.5.3.3 Airline Requirements
As operators, the airlines ultimately finance B-2707 induced airport modifications. Airline requirements will receive prime consideration for this reason. These requirements are stated through the airlines SST committee as well as individually. In addition to general requirements which flow to the contractor in the form of program direction and guidance, other specific requirements will be generated by the airlines from an operations and facilities utilization standpoint. Specific requirements will include gate positioning, passenger, baggage, and cargo handling, related passenger accommodations within the terminal facility, and operations at maintenance bases and route stations.

5.5.3.4 Local Government Requirements
Local government requirements are expected to be generated from three basic areas. These are: non-U. S. government air traffic and airport regulatory agencies, local government customs, and local government construction regulations. Requirements of these agencies are well known to the local airport operator and operating airlines. To facilitate the evaluations, the company will normally rely on the airport operator and operating airline to define these requirements.

5.5.3.5 Airplane Requirements
To assure integration of the B-2707 with its airport facilities, it is necessary to evaluate the airports as they are anticipated to be when the B-2707 enters service. As a result, it is necessary to take into account the requirements of current and proposed aircraft which will precede it into service. The characteristics and requirements of these airplanes will be obtained from the appropriate organizations within the Commercial Airplane Division of the Boeing Company. This procedure will also ensure that B-2707 requirements are compatible with B-747 and other transports requirements to the extent practicable.

The particular airplane characteristics to be evaluated will include its physical size, weight, landing gear characteristics, ground maneuvering capability, passenger baggage and cargo handling attributes, maintenance and servicing requirements, as well as requirements associated with the ground handling and servicing equipment.

5.5.4 Airport Selection
The selection of airports to evaluate for suitability of B-2707 operations is important from the standpoint of time phasing, and magnitude of effort. At the same time the coverage must be sufficiently broad to ensure an accurate estimate of economic investment requirements.

The selection criteria used to develop a list of world airports to be evaluated is described in the following paragraphs.

The world's airports are classified as U. S. and non-U. S. The criteria is somewhat different in each case since 15 of the major domestic airports have already been selected. Grades of priority were established, and each of the U. S. and non-U. S. airports assigned to one grade. The priority listing indicates the sequence in which the airports are planned to be evaluated.

First, a time-phased list of airline acquisition of the B-2707 was established. Next, based on the individual airline route structure analysis, the most desirable routes with a minimum leg of 1,000 nmi were selected. The airports thus listed were cross checked and reordered, with respect to traffic volume and number of airlines using the airport. To this list were added maintenance and overhaul bases for the domestic airlines participating in the SST program, and prototype test bases.

First-priority will be given to the 15 previously selected U. S. airports and the five airports in the U. S. which are planned for use in the prototype flight test program. Following these 20 airports, second-priority is given the top 20 listed non-U. S. airports. Third-priority is given to the next group of U. S. and non-U. S. airports. These include the domestic overhaul bases for the U. S. flag airlines. The priority three non-U. S. airport list gives some consideration to obtaining a world-wide spread rather than concentration according to traffic. Priority four contains additional U. S. and non-U. S. airports, which may be evaluated during Phase IV or V.

5.5.5 Data Acquisition
The task of gathering airport data follows the definition for requirements and airport selection. The task of data collection requires the cooperation of all participating and effected organizations. Sufficiently detailed data have never been centrally collected. Collection of airport data is also essential to the support of economic investment

analysis, airport and community noise evaluations and airlines facility planning.

The procedure to be followed in the acquisition of data will include the preparation of a standard questionnaire to be sent to each of the airport operators and airlines selected for evaluation. The questionnaire will be followed by coordination with the selected airport or airline offices as required to ensure complete data acquisition. The questionnaires will be sequenced in accordance with the airport and airline selection sequence described in Par. 5.5.4.1. Requisite data to be collected will include the following as a minimum:

- Pavement and subgrade data
- Underground structures and overpasses
- Refueling facilities
- Holding area and apron size and geometry
- Runway length
- Taxiway geometry (fillet size)
- Passenger, cargo, baggage handling and servicing facilities
- Fire and rescue equipment
- Engine blast protection
- Other maintenance, support, and operational facilities which may be required for normal SST operations

In addition to these requirements, acquisition of aerial photos for each airport is desirable. This approach commends itself from the standpoint of economy of manpower (drawings of the airport and terminal area are eliminated), aptness of data presentation, and in addition is essential for most airports in determining fillet radii requirements since up-to-date drawings are not always available. These photographs will also serve the requirements of the airport and community noise analysis.

5.5.6 Characteristics Evaluation

The analysis effort leading to definition of B-2707 requirements will consist of a comprehensive evaluation of all aspects of interaction between the airplane and ground facilities from airport location and siting through airport lighting. A detailed description of items to be analyzed is contained in subsequent paragraphs. These items will be evaluated for the comparison airplane as well as the B-2707 for each of the selected airports and commercial airlines.

5.5.6.1 Airport Location and Siting

Each airport will be evaluated to determine the portion of the facilities to be utilized for B-2707 ground operations. The geophysical location and general airport layout will have a direct bearing on such things as critical runway length, runway, taxiway and apron use, and ground handling flow of the airplane between facilities.

5.5.6.2 Airport Geometry

This aspect of the airport facilities will be analyzed for runway, taxiway and apron dimensions, ground maneuvering space, and pavement slopes. The capability of those elements will be analyzed against the airplane requirements as dictated by: airplane configuration, landing gear arrangement, ground maneuvering capability, and performance capability for runway critical lengths at prescribed gross weights under the particular geophysical conditions of the designated airports.

5.5.6.3 Strength Analysis

The various airport pavements and substructures will be analyzed for strength capability against the landing gear arrangement and loads using methods acceptable to the airport authorities.

5.5.6.4 Engine Effects

Engine intake and exhaust clearances and blast effects on fixed and mobile facilities will be defined on the basis of engine inlet/exhaust temperature, velocity, and acoustic contours. These effects will be considered during all phases of ground operations.

5.5.6.5 Airport/Community Noise

The airport and community noise levels associated with landing, takeoff, ground maneuver, and engine runup must be within established limits. This particular characteristic has been recognized as an extremely important element of suitability. As such, it has been given special emphasis in the Airport and Community Noise Program, V4-B2707-4. The results of the evaluations conducted under the noise program will be coordinated with the airport operators in conjunction with the results of the suitability evaluations as described in this plan.

5.5.6.6 Passenger, Baggage, and Cargo Handling

The terminal facilities will be evaluated for handling capability. This will include terminal effects of the various docking positions as well as

the quantity of passengers and commodities processed. This evaluation will be based on the door locations in the B-2707 and the terminal passenger, baggage, and cargo handling equipment.

5.5.6.7 Airline Facilities
The service and maintenance facilities required at maintenance bases and line stations as well as training facilities will be analyzed. Servicing facility requirements will be determined for the airplane and ground support equipment. Airline maintenance overhaul, training, and support facility requirements will be based on the airplane and ground support equipment characteristics, and maintenance, and operational field engineering requirements. Specific airline requirements, with respect to inventory size and mix, and mode of operation will also be included.

5.5.6.8 Air Traffic Control Ground Support Facilities
This task will consist of a definition of requirements of new or modified ground system installations to support items such as instrument landing systems. Impact of national airspace compatibility is discussed in Sec. 3.0 and Par. 5.3.2.

5.5.6.9 Lighting, Fire, Safety
The airport lighting will be analyzed to ensure that ramp illumination is satisfactory and that light relocation requirements conform to pavement geometry modifications. Fire and safety equipment requirements will be evaluated against airplane configuration and capacity.

5.5.7 Definition of B-2707 Requirements
Since the B-2707 will not enter service until the 1974 time period it is necessary to identify the requirements of new airplanes which will precede it into service. These new models will include the DC-8-60 series, B-747, and the British-French supersonic Concorde. The current airport configuration as reflected in aerial photographs will be updated to indicate modifications included in the airport master plans. Based on the resulting airport configuration, the requirements engendered by each of the advanced airplanes, will be identified. Those requirements which are in excess of the requirements of any of the airplanes which precede the B-2707 into service will be assessed against the B-2707. Facility investment cost will then be estimated. This procedure will be followed for the airport facilities as well as the airline facilities. The airport and airline requirements for new or modified facilities thus identified will be documented for use in the integration functions described in subsequent sections of this plan.

5.5.8 Evaluation Feedback
After the B-2707 unique facility requirements have been identified they will be made available to the design project. This feedback of requirements permits re-evaluations and changes of design, resulting in an optimized balance between the airplane and ground support facilities.

5.5.9 Cost Estimates
Although investment costs are paid for over a period of years, and charged against all using aircraft on one basis or another, the procedure to be followed will parallel the allocation of requirements. The first introduced airplane which creates a new need will be allocated the total excess requirement and associated investment costs. If an airplane creates a requirement on being introduced into service, that requirement must be met and would exist if no new aircraft were subsequently introduced. Based on this rationale, investment costs of B-2707 peculiar requirements will be estimated and allocated to either Government or airlines as appropriate. The time phasing of these investments will be based on the sequenced introduction of the B-2707 into service with the investment preceding the introduction by one year.

The investment required by the airlines and the Government in any year is dependent on the number of airlines receiving their first delivery in the subsequent year, their route structures, and the number of airlines using a particular airport. Since it is not possible to evaluate every potential B-2707 airport or operating airline, it is necessary to extrapolate the results of these definitive analyses to cover the full spectrum of the program. These investment requirements will be determined in support of the economic analysis and annual report.

5.5.10 Documentation
The documentation which will be produced and/or updated during Phase III and used in subsequent coordination as the primary tools of assuring system integration is shown on the document tree Fig. 5-13. These documents and their function in the integration process are as follows:

a. Airport Suitability - Airline Facilities Plan. This plan defines the tasks, methods,

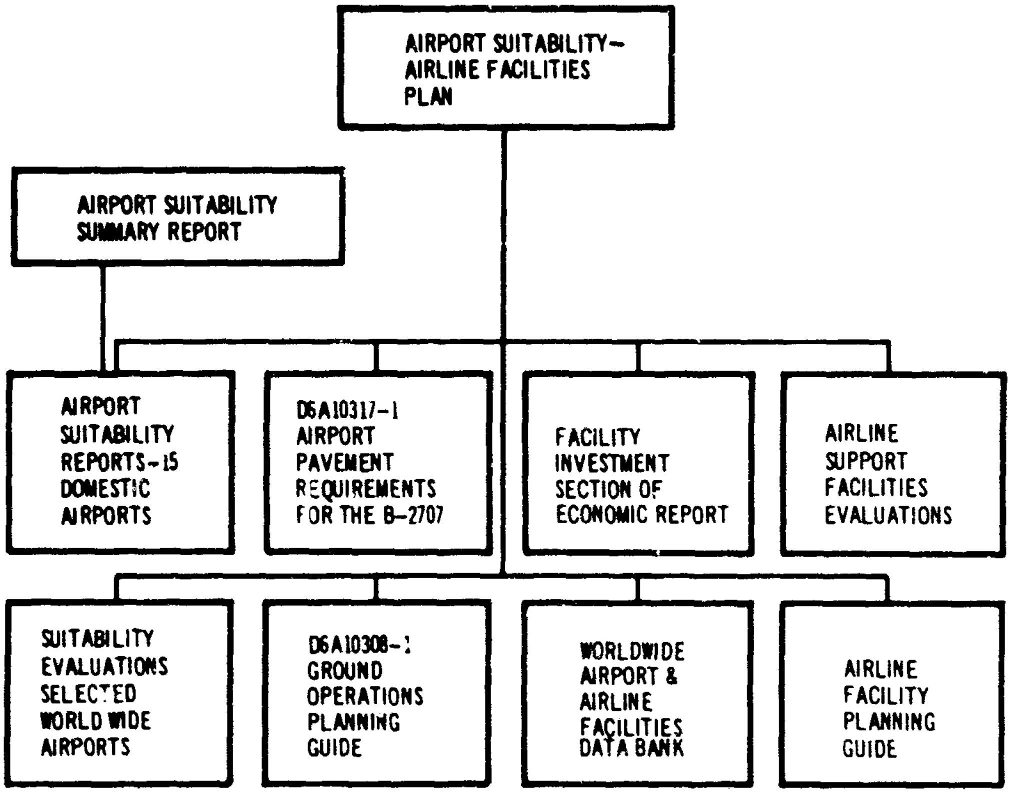


Figure 5-13. Airport Suitability-Airlines Facilities Document Tree

tools, organization, and schedule necessary to accomplish the program assuring the successful integration of the B-2707 with its ground operational facilities environment.

b. Airport Suitability Reports - 15 Domestic Airports. These updated reports present the results of the suitability evaluation of these airports with the requirements of the B-2707. These reports are coordinated with the individual airport operators for their planning use, evaluation, and comments.

c. Airport Suitability Summary Report. This report is transmitted to the FAA, the Airport Operators Council, and the Airlines Committee for their planning use and evaluations of program progress.

d. Suitability Evaluations - Selected Worldwide Airports. This documentation presents the results of the suitability evaluations with respect to selected worldwide B-2707 airports other than the preselected 15 U. S. airports. These reports are coordinated with the individual airport operators for their planning use.

e. Pavement Requirements Analysis. This document presents an analysis of the airplane's pavement requirements in accord with the currently accepted methods of analysis. It also includes the pavement design charts necessary to determine thickness requirements to evaluate existing pavements.

f. Ground Operations Planning Guide. This document presents airplane data, requirements, and criteria necessary to the planning of airports for B-2707 operations. It is one of the fundamental tools of the integration process and is transmitted to airport operators and airport designers for their planning and design information.

g. Economic Report. The facility investment section of this report is based on the technical evaluation studies which are included in other documents on the tree. The investment costs are included in the Economic Report to the FAA for evaluation of the economic implications of the program.

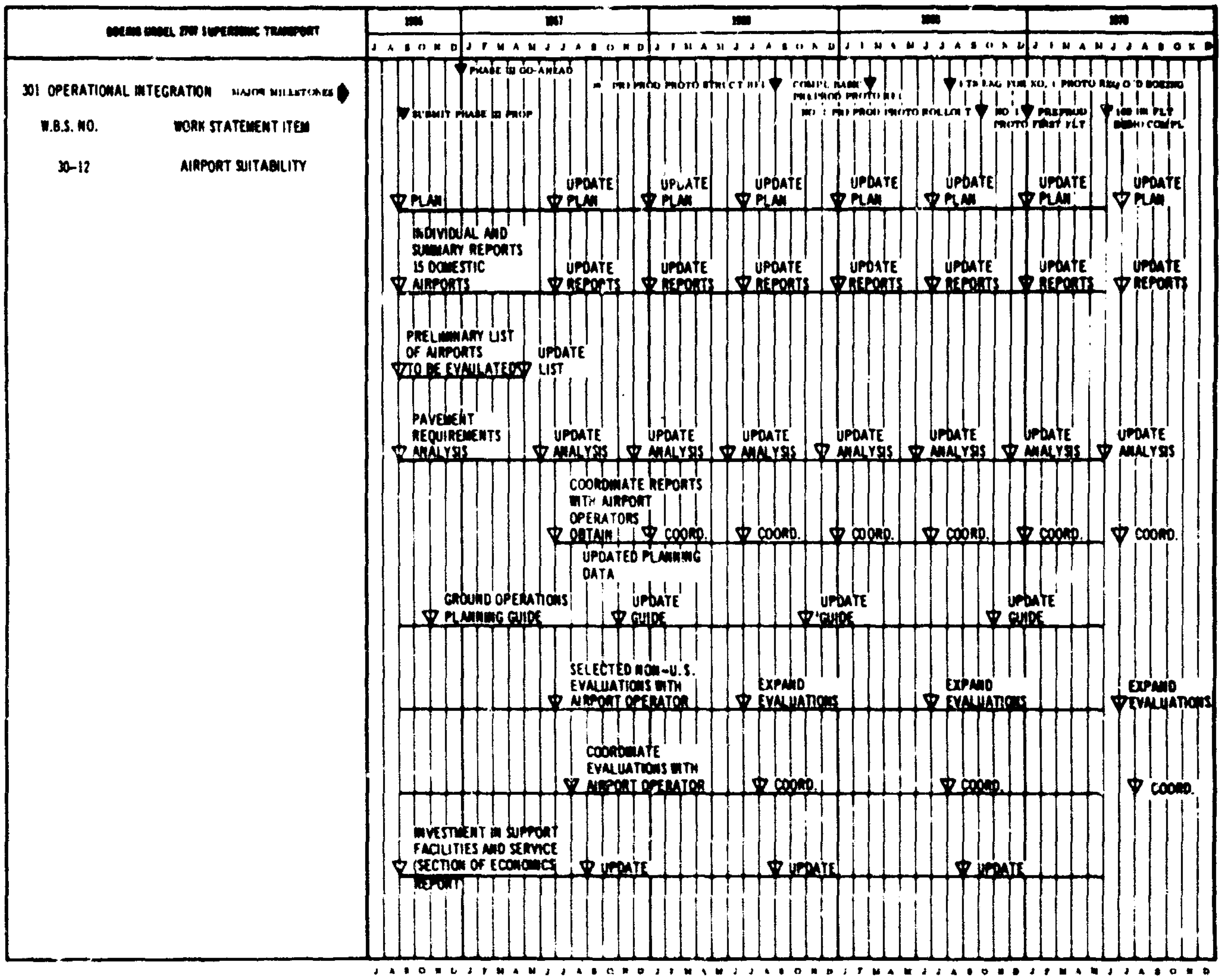


Figure 5-14. Airport Suitability Phase III Schedule

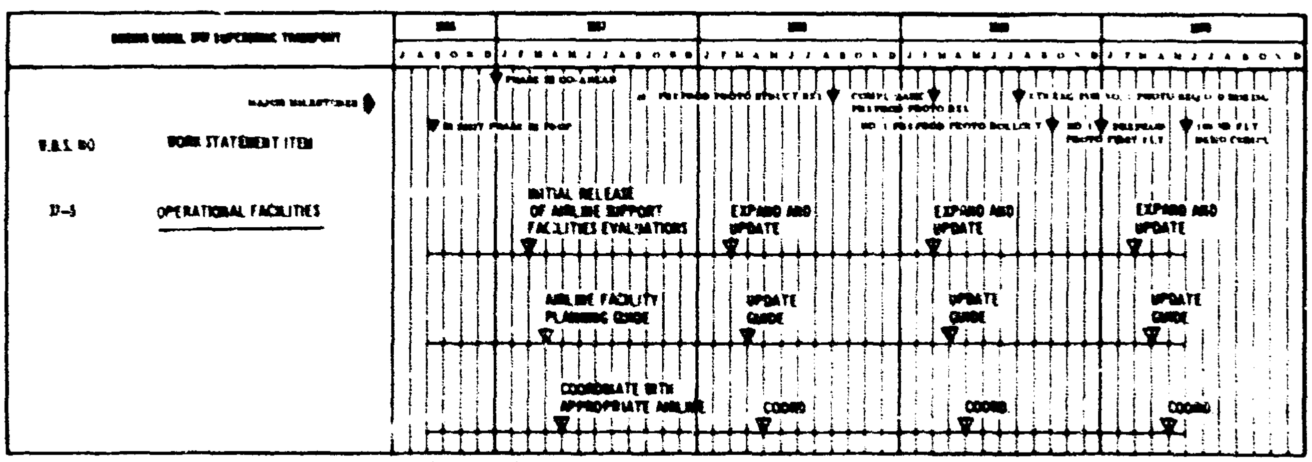


Figure 5-15. Operational Facilities Phase III Schedule

h. Airline Support Facilities Evaluations. These evaluations of airline support facilities present a definition of B-2707 facility requirements which must be satisfied for successful integration. These documents are coordinated with the individual appropriate airlines to assist them in the planning and implementation necessary to achieve operational compatibility.

i. Airline Facility Planning Guide. This document presents the B-2707 planning factors which must be included in the design of airline maintenance, overhaul, training and support facilities. It is released to, and coordinated with the airlines to support their B-2707 facility planning effort. It is essential to the planning effort of those airlines not treated in the above evaluations documents.

j. Worldwide Airport and Airline Facility Data Bank. Although not properly a document, the data bank is included on the document tree to show that a depository is planned for the retention and use of this information.

5.5.11 Coordination
Coordination of the results of these evaluations with the FAA and appropriate elements of the individual airlines and airport operators will be conducted on a continuing basis to ensure the proper acquisition of appropriate evaluation data as well as to assure an appropriate level of support in their planning and implementation activities.

5.5.12 Schedules, Phase III
The schedule of events controlling the activities defined in this program are shown on Figs. 5-14 and 5-15.

5.6 TRAINING AND TRAINING EQUIPMENT PROGRAM
The B-2707 training and training equipment program and its development are described in document Training and Training Equipment Program, V4-B2707-7. As indicated in Fig. 5-16 Boeing will continue to coordinate with the FAA, airlines and airport operators in the analyses of flight crew, maintenance personnel, and support personnel tasks and functions. Training requirements will be established and the training program will be developed in detail based upon a thorough analysis of B-2707 systems and the identification of those task and functions requiring new skills or knowledge. The initial training programs will be designed to train company and FAA personnel in support of the manufacture of two prototype airplanes and the 100-hour flight test program. Flight and ground test programs will be monitored and performance standards, training requirements and training objectives will be refined. Appropriate changes in course content will be incorporated as additional information is obtained from flight test, ground test, and simulation programs.

5.6.1 Flight Crew and Operations Training
During Phase III, the flight crew training program will be conducted for Company and FAA experimental test crews. A customer airline orientation program will also be developed. Training for backup crews and FAA personnel will be scheduled during the six months preceding first flight. The engineering flight deck systems integration simulator (FDSIS) will be the primary training device used during Phase III for aircrew training. FDSIS time will be allocated for orientation programs for key airline personnel.

During Phase IV, the initial Boeing instructor pilots and flight engineers needed to support customer requirements and backup flight test operations personnel will be trained. The program to check out chief pilots and airline operational planning personnel will also be conducted during Phase IV. During Phase V, the training program will be oriented toward the qualification and checkout of instructor crews for the airlines. Boeing will assist the airlines as required in developing their training programs for flight crew and operations personnel.

5.6.2 Maintenance Training
Early in Phase III, maintenance training will be initiated for Boeing personnel, FAA personnel and other selected personnel who are concerned with, or who will perform maintenance, servicing, test, inspection, and troubleshooting in support of the B-2707 prototype, its subsystems and support equipment. Systems maintenance requirements will be established, and specialist courses will be conducted as required. Classroom instruction will be supported by preliminary maintenance manuals, charts, graphics, course syllabus and student guides for classroom and laboratory training. A program of training evaluation, including post-training on-the-job performance evaluation, and training refinement will be maintained throughout Phase III.

During Phase IV, data derived from the Phase III evaluation program will be used to refine the training program. Refined courses for selected

airline, FAA, and Boeing personnel such as supervisory and planning personnel and production maintenance personnel will be conducted during Phase IV. Specific training requirements for customer airlines will be determined, training programs will be established and courses tailored to airline's requirements will be developed. The airlines' training programs will be conducted and assistance in developing their training programs will be provided during Phase V.

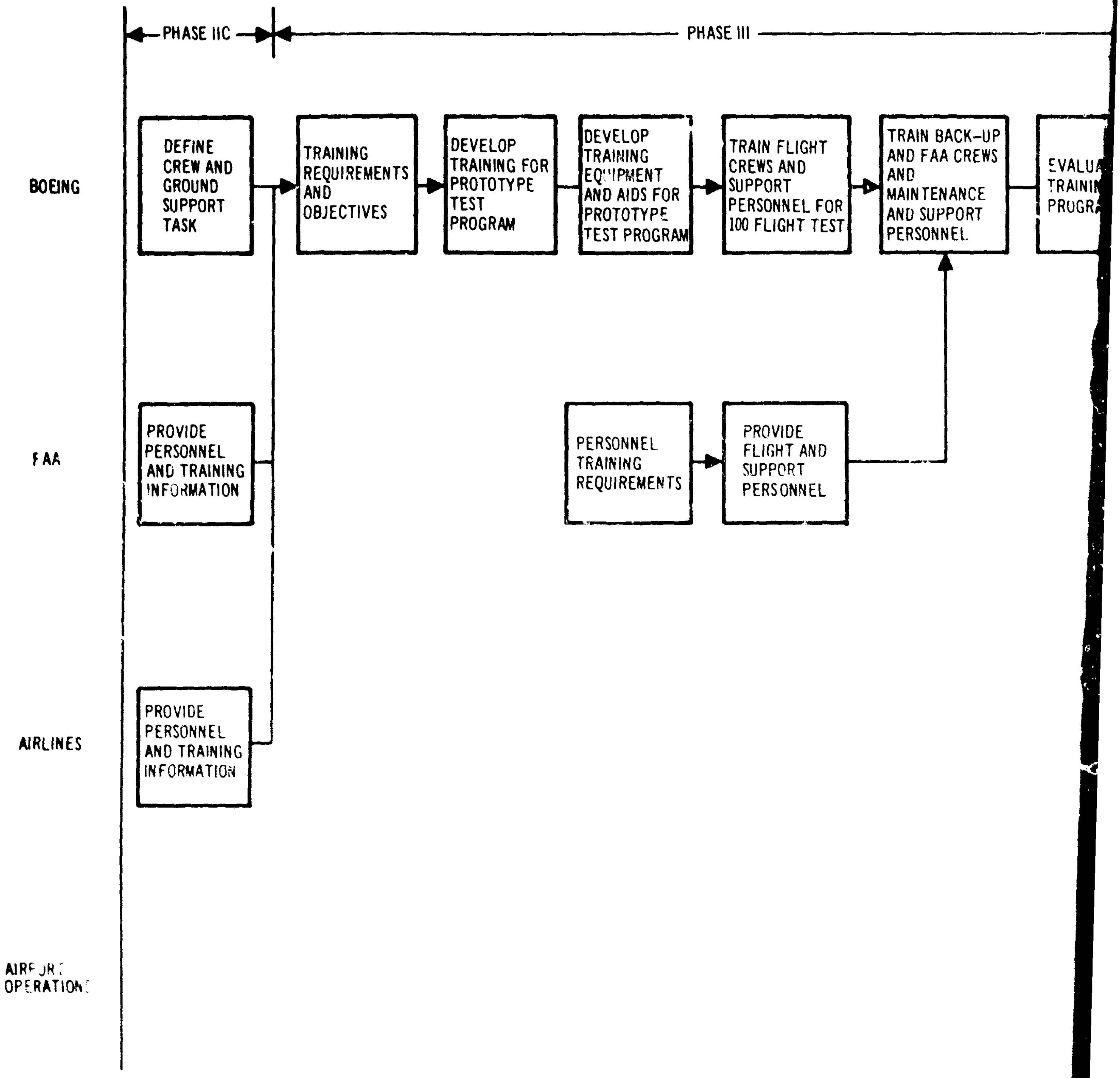
5.6.3 Support Personnel Training

Phase III orientation courses will be developed for the training of personnel required to support B-2707 flight operations. Training courses will be conducted for air traffic controllers, crash rescue personnel, and tower operators associated with the facilities utilized in the test program. Ground operations training programs will be expanded during Phases IV and V to include courses for dispatchers, cabin attendants, performance engineers, and airport operations support personnel.

5.7 OPERATIONAL INTEGRATION PROGRAM PHASING

Figure 5-17 is the schedule of events comprising the company part of the operational integration program. Also shown is reference to the airline committee activities, ICAO conferences, SAE committee on standardization, ARINC committee meetings, which will be supported and attended as means of discerning and accommodating domestic and international airlines' and airport operators' operational requirements.

Necessary actions for FAA, airlines, and airport operators, as shown on Fig. 5-18, are postulated to allow orderly progression of the program. The numerous and on-going coordinations with each of these agencies are not shown. Liaison with the NASA and the Air Force are not specifically shown, but will occur at frequent intervals in order to keep abreast of pertinent programs (e.g., B-70). A group of 15 cognizant engineers, for example, was identified in Phase II-C to coordinate with AFFTC on a regular basis. This will continue into succeeding phases.


PHASE IIC
PHASE III
BOEING
FAA
AIRLINES
AIRPORT OPERATIONS
DEFINE CREW AND GROUND SUPPORT TASK
TRAINING REQUIREMENTS AND OBJECTIVES
DEVELOP TRAINING FOR PROTOTYPE TEST PROGRAM
DEVELOP TRAINING EQUIPMENT AND AIDS FOR PROTOTYPE TEST PROGRAM
TRAIN FLIGHT CREWS AND SUPPORT PERSONNEL FOR 100 FLIGHT TEST
TRAIN BACK-UP AND FAA CREWS AND MAINTENANCE AND SUPPORT PERSONNEL
EVALUA
TRAININ
PROGRA
PROVIDE PERSONNEL AND TRAINING INFORMATION
PERSONNEL TRAINING REQUIREMENTS
PROVIDE FLIGHT AND SUPPORT PERSONNEL
PROVIDE PERSONNEL AND TRAINING INFORMATION

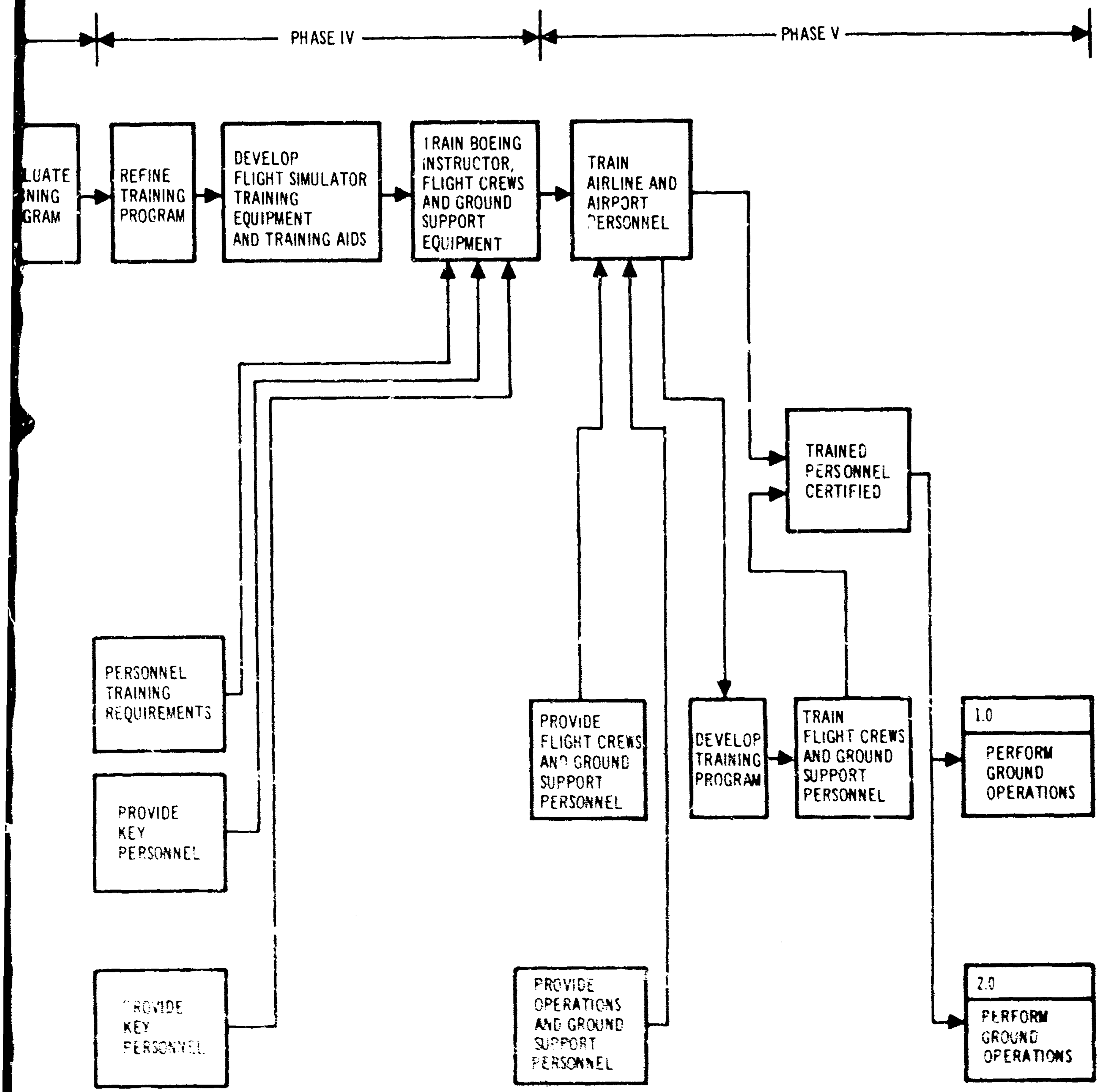
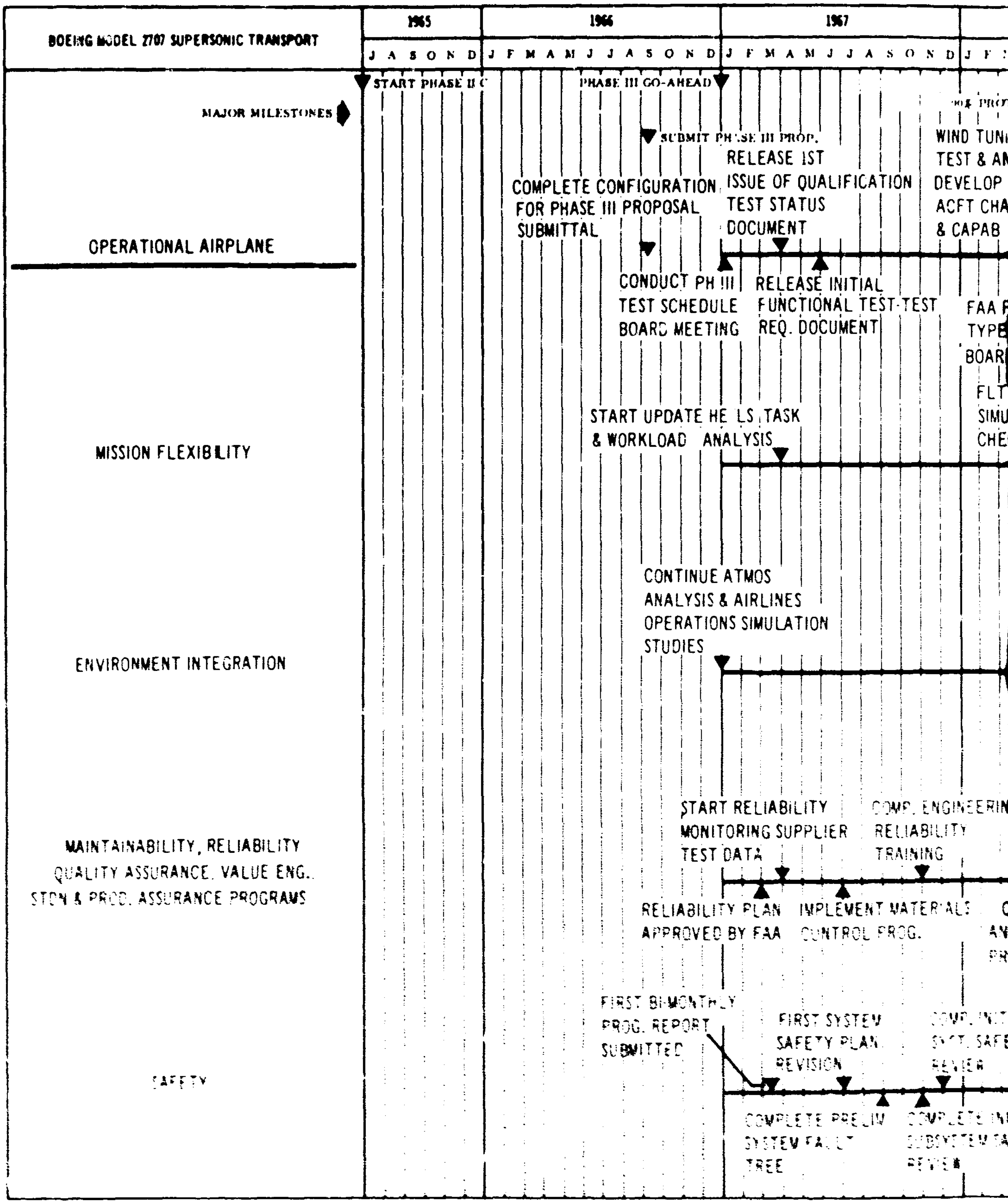


Figure 5-16. Operational Integration–Training Program Plan



BOEING MODEL 2707 SUPERSONIC TRANSPORT
1965
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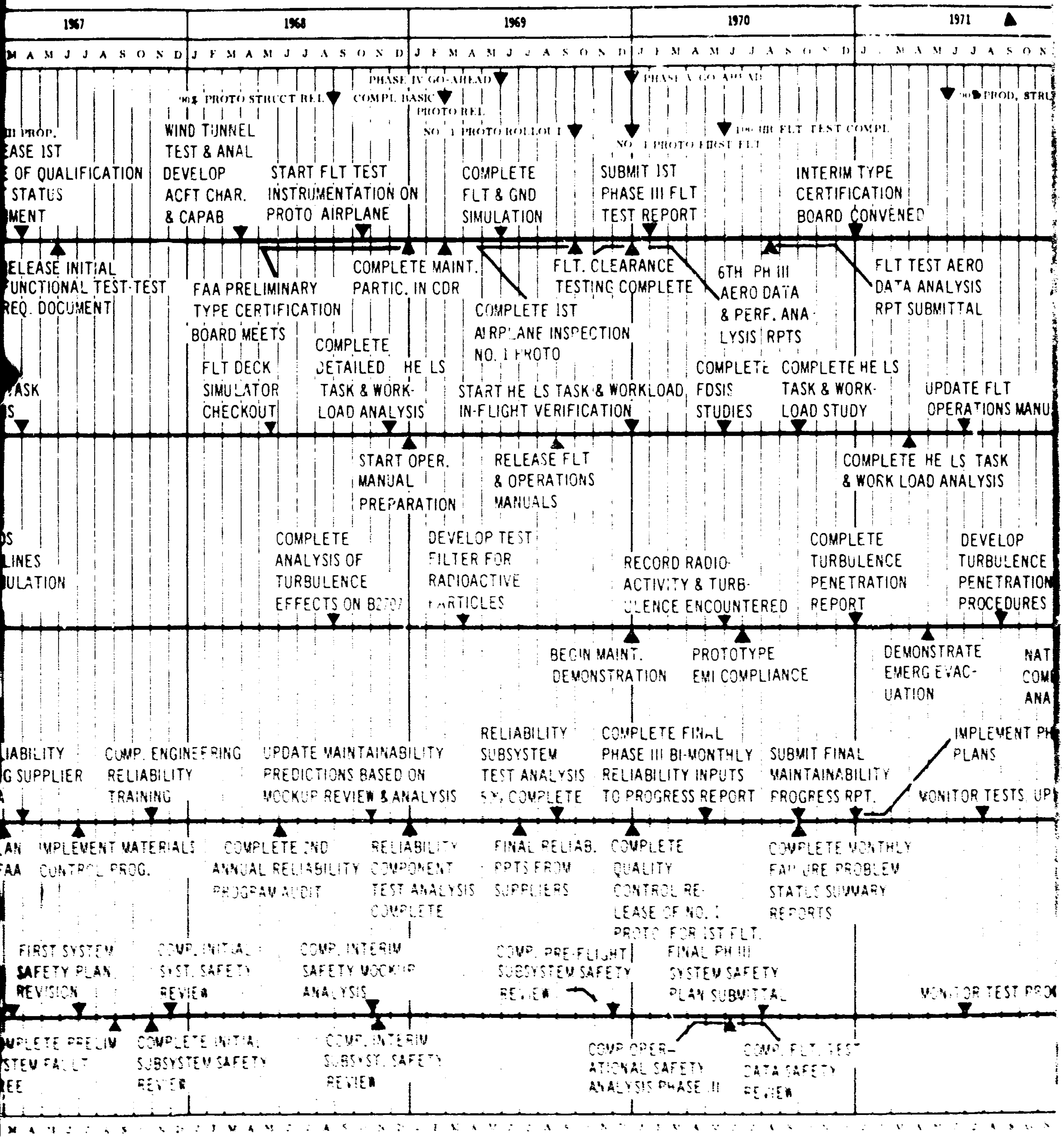
1967
J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
START PHASE II C
PHASE III GO-AHEAD
MAJOR MILESTONES
SUBMIT PHASE III PROP.
RELEASE 1ST ISSUE OF QUALIFICATION TEST STATUS DOCUMENT
COMPLETE CONFIGURATION FOR PHASE III PROPOSAL SUBMITTAL
OPERATIONAL AIRPLANE
CONDUCT PH III TEST SCHEDULE BOARD MEETING
RELEASE INITIAL FUNCTIONAL TEST-TEST REQ. DOCUMENT
START UPDATE HE LS TASK & WORKLOAD ANALYSIS
MISSION FLEXIBILITY
CONTINUE ATMOS ANALYSIS & AIRLINES OPERATIONS SIMULATION STUDIES
ENVIRONMENT INTEGRATION
START RELIABILITY MONITORING SUPPLIER TEST DATA
RELIABILITY TRAINING
MAINTAINABILITY, RELIABILITY QUALITY ASSURANCE, VALUE ENG., STDN & PROD. ASSURANCE PROGRAMS
RELIABILITY PLAN APPROVED BY FAA
IMPLEMENT MATERIALS CONTROL PROG.
FIRST BI-MONTHLY PROG. REPORT SUBMITTED
FIRST SYSTEM SAFETY PLAN REVISION
SAFETY
COMPLETE PRELIM SYSTEM FAULT TREE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PHASE V GO-AHEAD
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90% PROD, STRU
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COMPLETE
FLT & GND
SIMULATION
SUBMIT 1ST
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BOARD CONVENED
RELEASE INITIAL
FUNCTIONAL TEST-TEST
REQ. DOCUMENT
FAA PRELIMINARY
TYPE CERTIFICATION
BOARD MEETS
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AIRPLANE INSPECTION
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& PERF. ANA-
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FLT TEST AERO
DATA ANALYSIS
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TASK & WORK-
LOAD ANALYSIS
START HE LS TASK & WORKLOAD
IN-FLIGHT VERIFICATION
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PREPARATION
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& OPERATIONS
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COMPLETE HE LS TASK
& WORK LOAD ANALYSIS
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ANALYSIS OF
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EFFECTS ON B2707
DEVELOP TEST
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RADIOACTIVE
PARTICLES
RECORD RADIO-
ACTIVITY & TURB-
ULENCE ENCOUNTERED
COMPLETE
TURBULENCE
PENETRATION
REPORT
DEVELOP
TURBULENCE
PENETRATION
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COMPLETE FINAL
PHASE III BI-MONTHLY
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TO PROGRESS REPORT
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MAINTAINABILITY
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IMPLEMENT MATERIALS
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REVIEW
COMP. INTERIM
SAFETY MOCKUP
ANALYSIS
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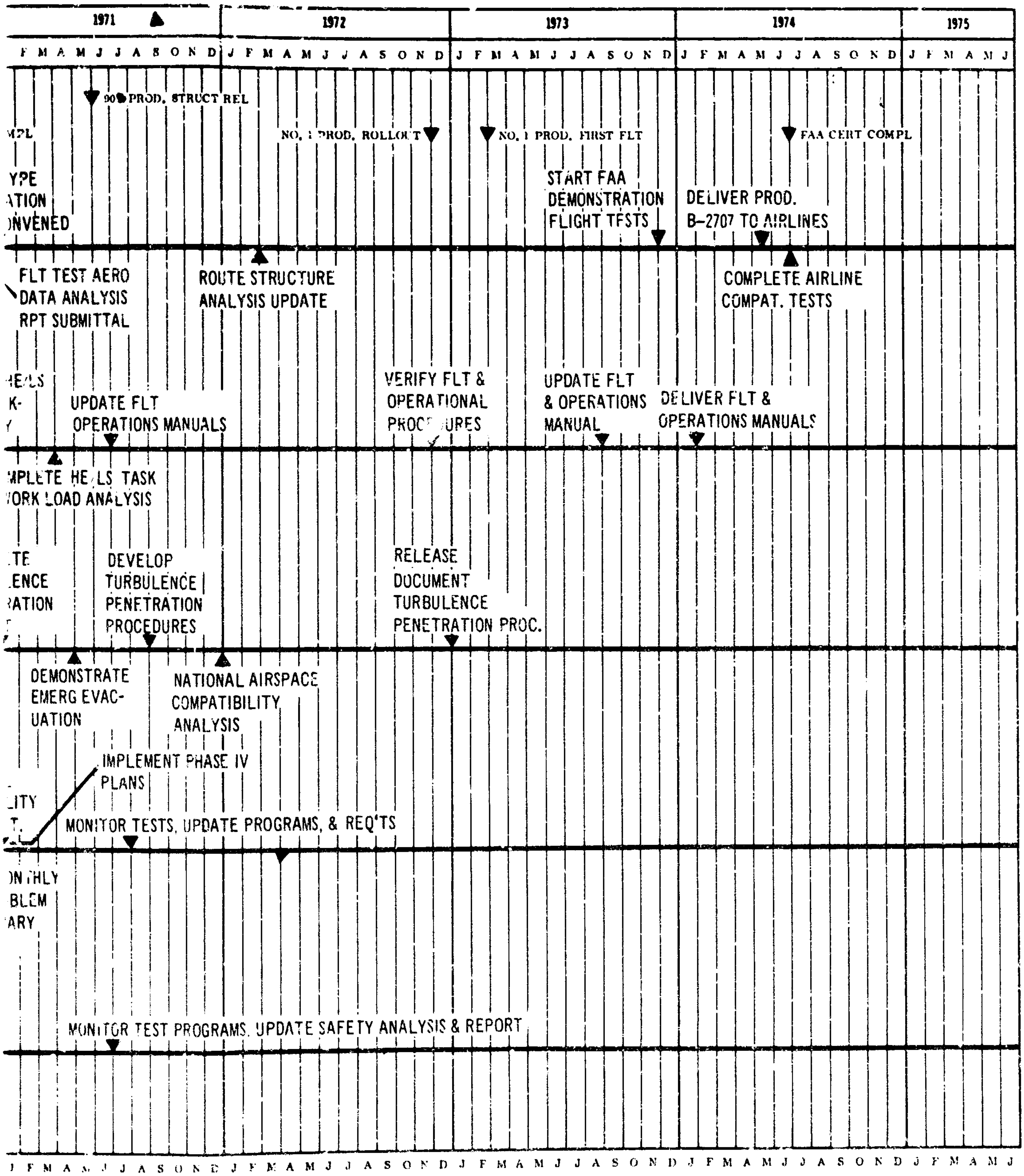
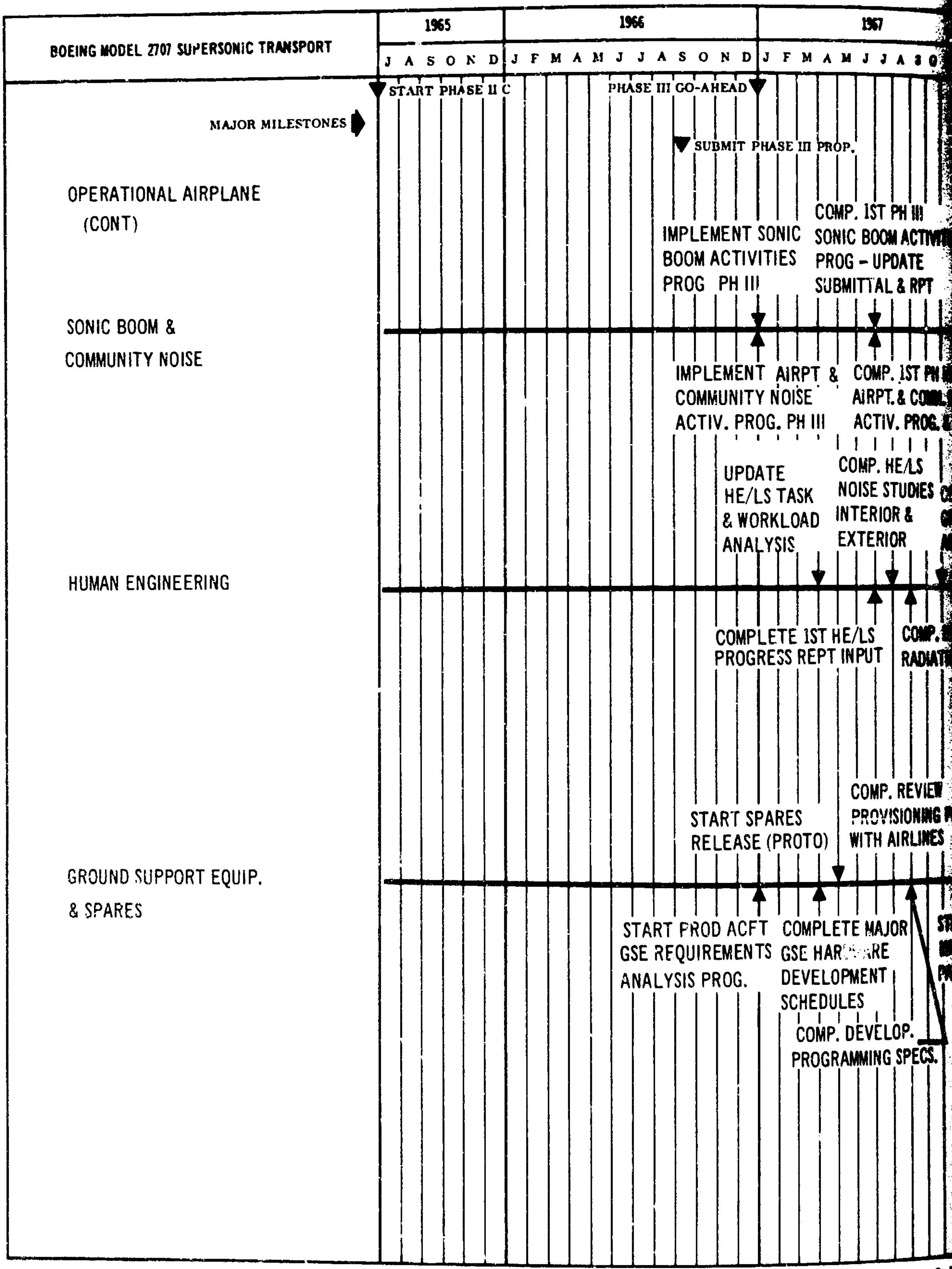


Figure 5-17. B2707 Operational Integration Program Phasing


BOEING MODEL 2707 SUPERSONIC TRANSPORT
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SUBMIT PHASE III PROP.
OPERATIONAL AIRPLANE (CONT)
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SONIC BOOM & COMMUNITY NOISE
IMPLEMENT AIRPT & COMMUNITY NOISE ACTIV. PROG. PH III
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ACTIV. PROG.
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HUMAN ENGINEERING
COMPLETE 1ST HE/LS PROGRESS REPT INPUT
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RADIAT
COMP. REVIEW
PROVISIONING
WITH AIRLINES
START SPARES RELEASE (PROTO)
GROUND SUPPORT EQUIP. & SPARES
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COMPLETE MAJOR GSE HARDWARE DEVELOPMENT SCHEDULES
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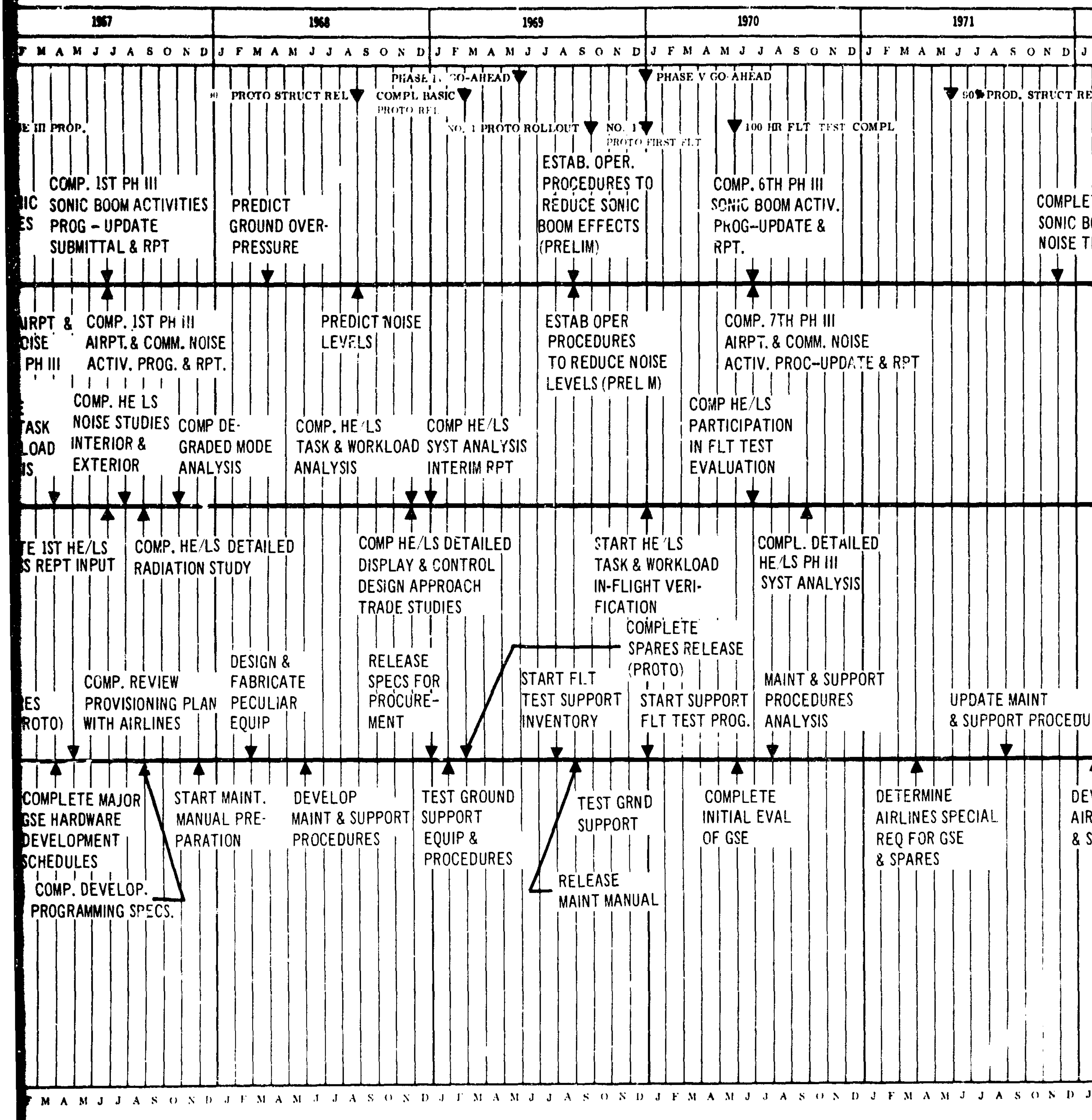

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ESTAB. OPER. PROCEDURES TO REDUCE SONIC BOOM EFFECTS (PRELIM)
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COMP. 7TH PH III AIRPT. & COMM. NOISE ACTIV. PROG--UPDATE & RPT
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COMP HE/LS PARTICIPATION IN FLT TEST EVALUATION
E 1ST HE/LS S REPT INPUT
COMP. HE/LS DETAILED RADIATION STUDY
COMP HE/LS DETAILED DISPLAY & CONTROL DESIGN APPROACH TRADE STUDIES
START HE/LS TASK & WORKLOAD IN-FLIGHT VERI-FICATION
COMPL. DETAILED HE/LS PH III SYST ANALYSIS
COMPLETE SPARES RELEASE (PROTO)
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DESIGN & FABRICATE PECULIAR EQUIP
RELEASE SPECS FOR PROCURE-MENT
START FLT TEST SUPPORT INVENTORY
START SUPPORT FLT TEST PROG.
MAINT & SUPPORT PROCEDURES ANALYSIS
UPDATE MAINT & SUPPORT PROCEDUR
COMPLETE MAJOR GSE HARDWARE DEVELOPMENT SCHEDULES
START MAINT. MANUAL PRE-PARATION
DEVELOP MAINT & SUPPORT PROCEDURES
TEST GROUND SUPPORT EQUIP & PROCEDURES
TEST GRND SUPPORT
COMPLETE INITIAL EVAL OF GSE
DETERMINE AIRLINES SPECIAL REQ FOR GSE & SPARES
DEV AIRL & SP
COMP. DEVELOP. PROGRAMMING SPECS.
RELEASE MAINT MANUAL

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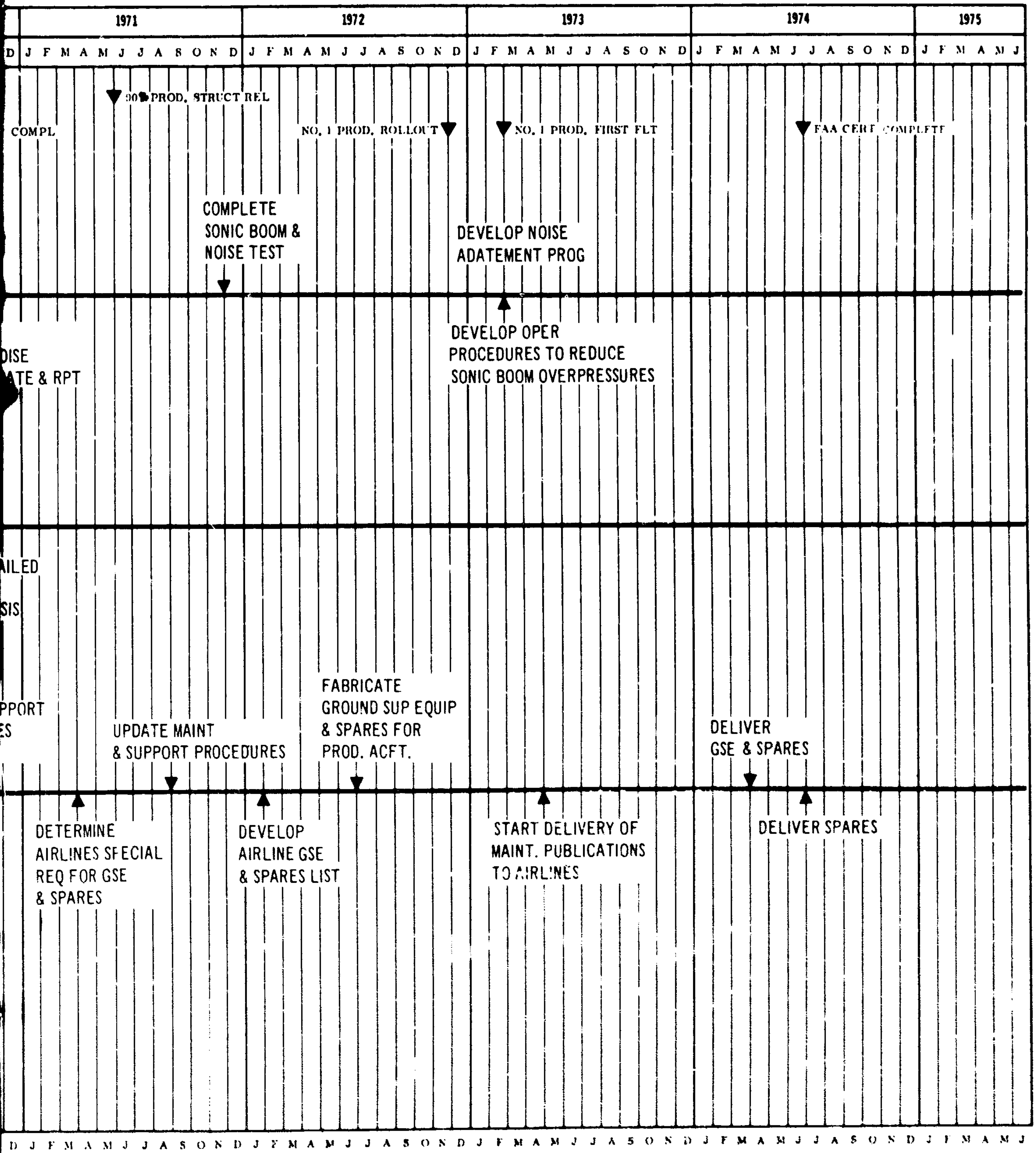
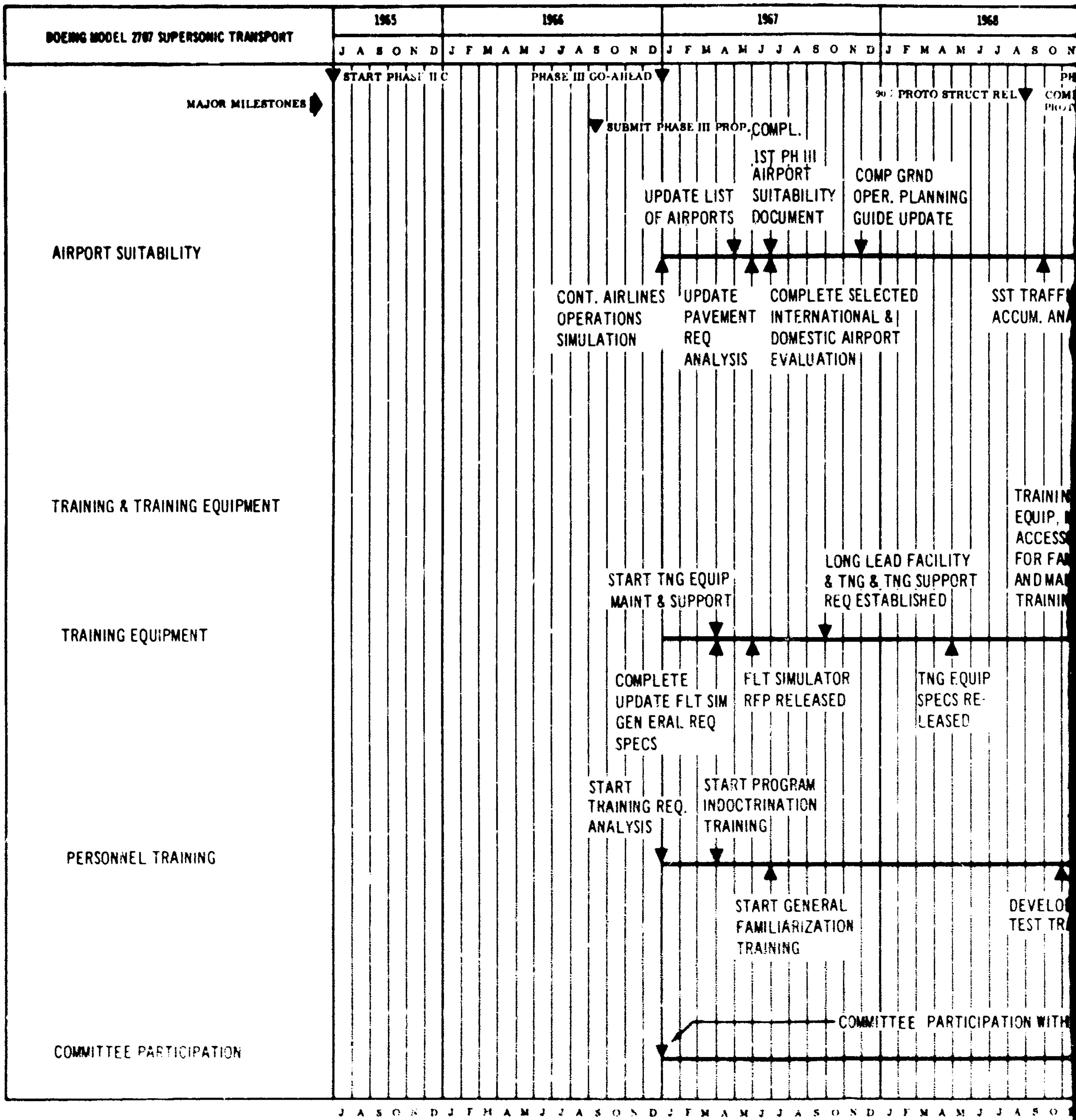


Figure 5-17. (Continued)


BOEING MODEL 2707 SUPERSONIC TRANSPORT
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MAJOR MILESTONES
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SUBMIT PHASE III PROP.
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AIRPORT SUITABILITY
COMPL. 1ST PH III AIRPORT SUITABILITY DOCUMENT
UPDATE LIST OF AIRPORTS
COMP GRND OPER. PLANNING GUIDE UPDATE
CONT. AIRLINES OPERATIONS SIMULATION
UPDATE PAVEMENT REQ ANALYSIS
COMPLETE SELECTED INTERNATIONAL & DOMESTIC AIRPORT EVALUATION
SST TRAFF ACCUM. AN
TRAINING & TRAINING EQUIPMENT
TRAINING EQUIPMENT
START TNG EQUIP MAINT & SUPPORT
LONG LEAD FACILITY & TNG & TNG SUPPORT REQ ESTABLISHED
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FLT SIMULATOR RFP RELEASED
TNG EQUIP SPECS RE-LEASED
PERSONNEL TRAINING
START TRAINING REQ. ANALYSIS
START PROGRAM INDOCTRINATION TRAINING
START GENERAL FAMILIARIZATION TRAINING
COMMITTEE PARTICIPATION
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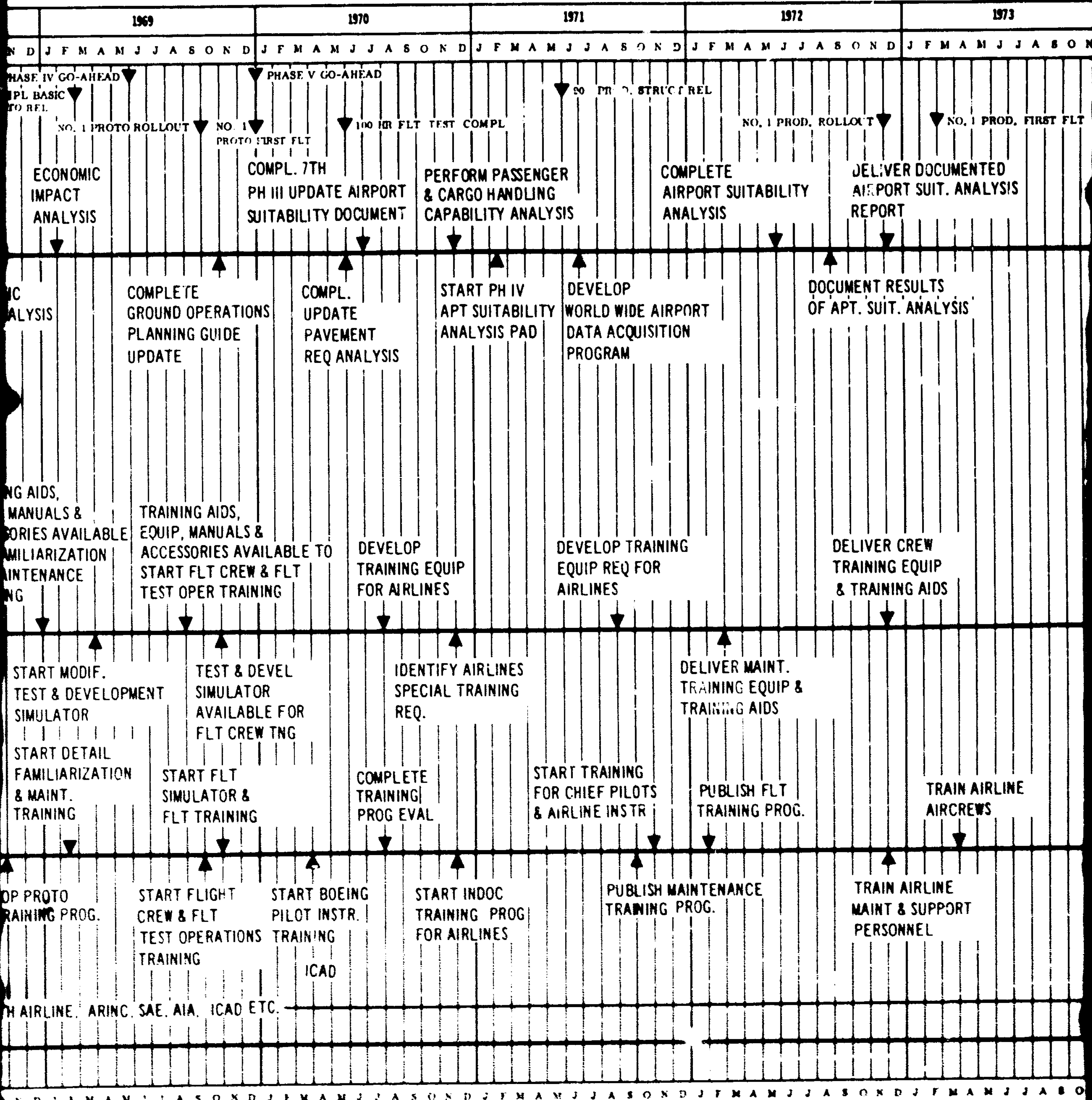

Figure 5-17. (Concluded

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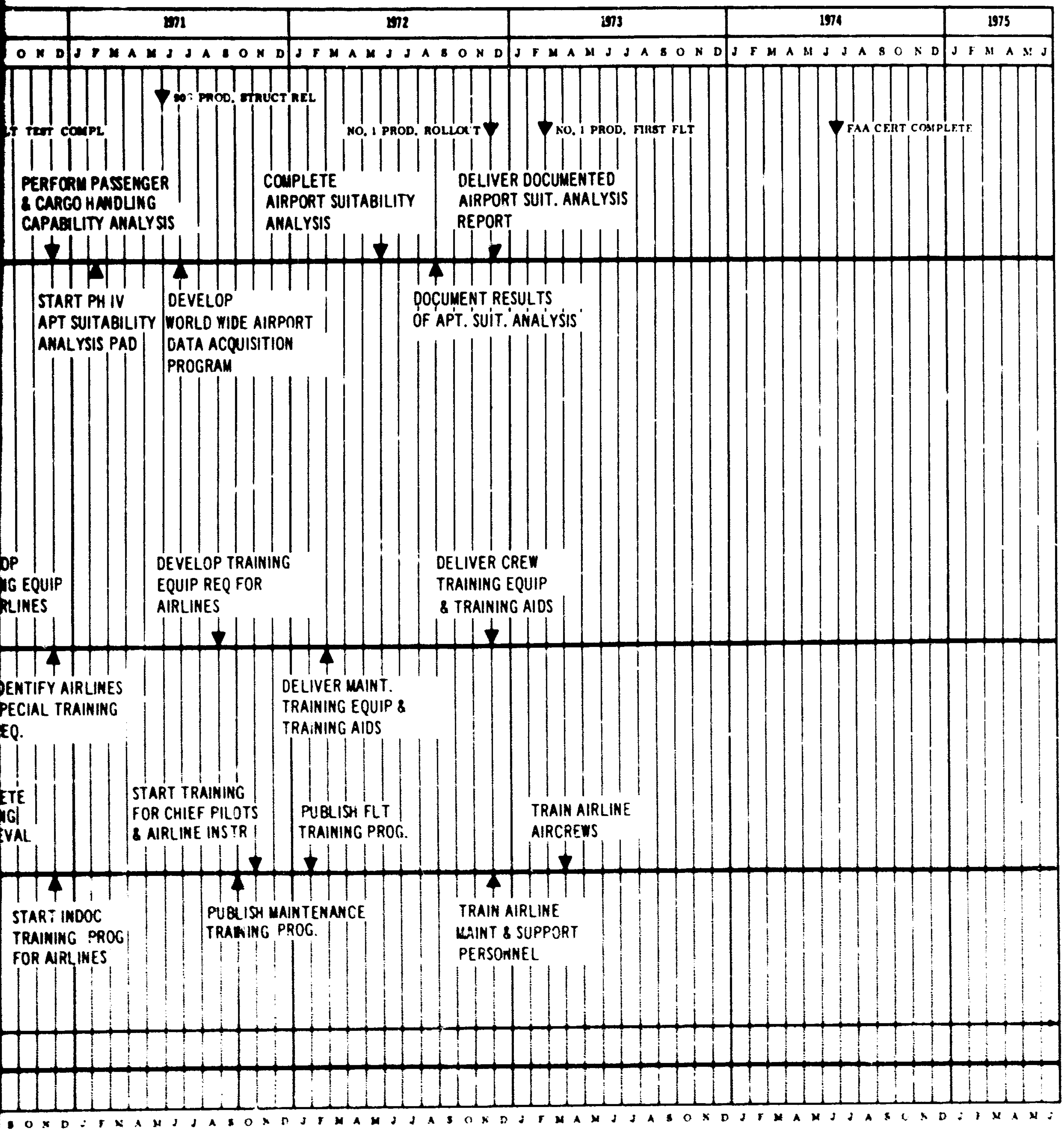
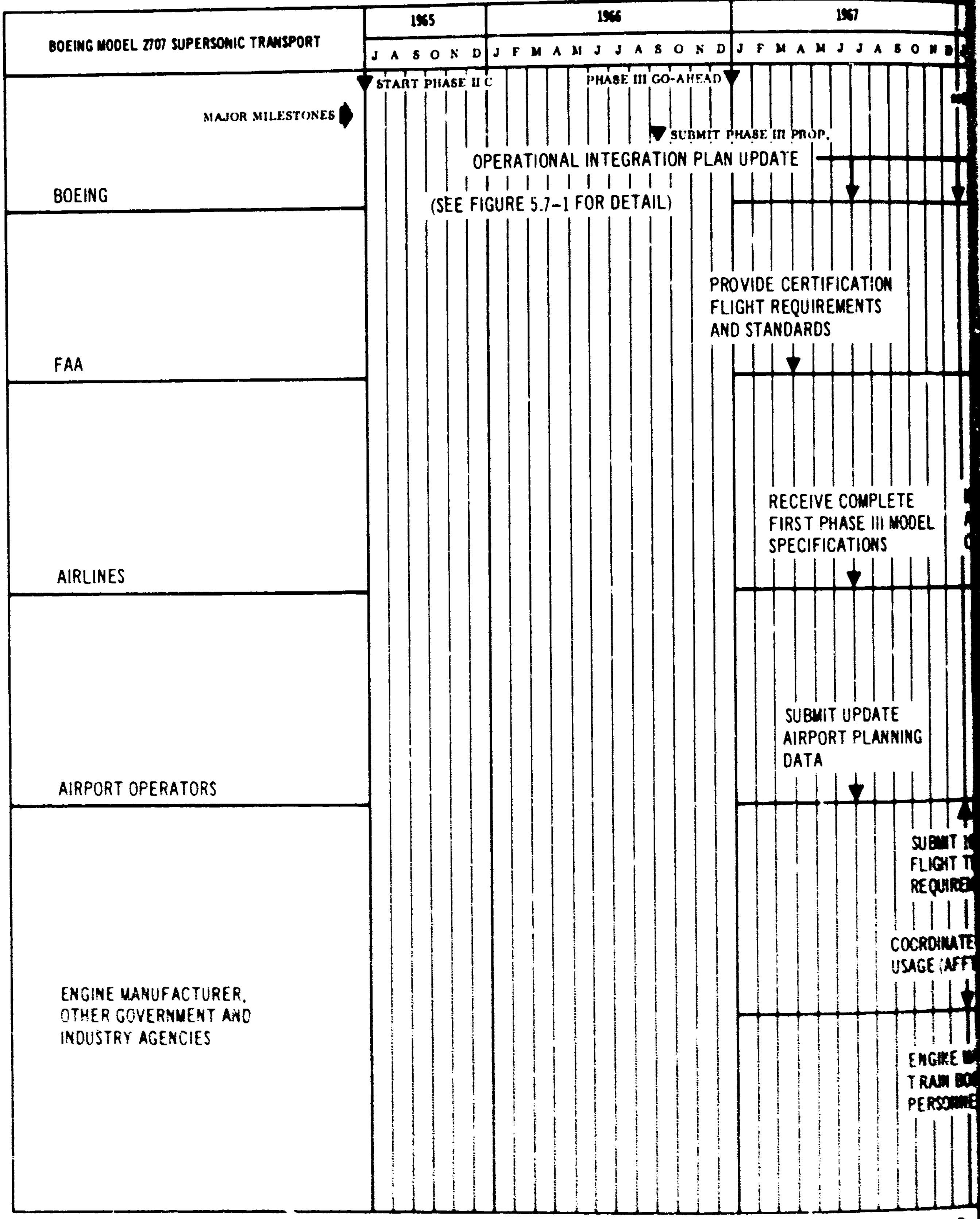


Figure 5-17. (Concluded)


BOEING MODEL 2707 SUPERSONIC TRANSPORT
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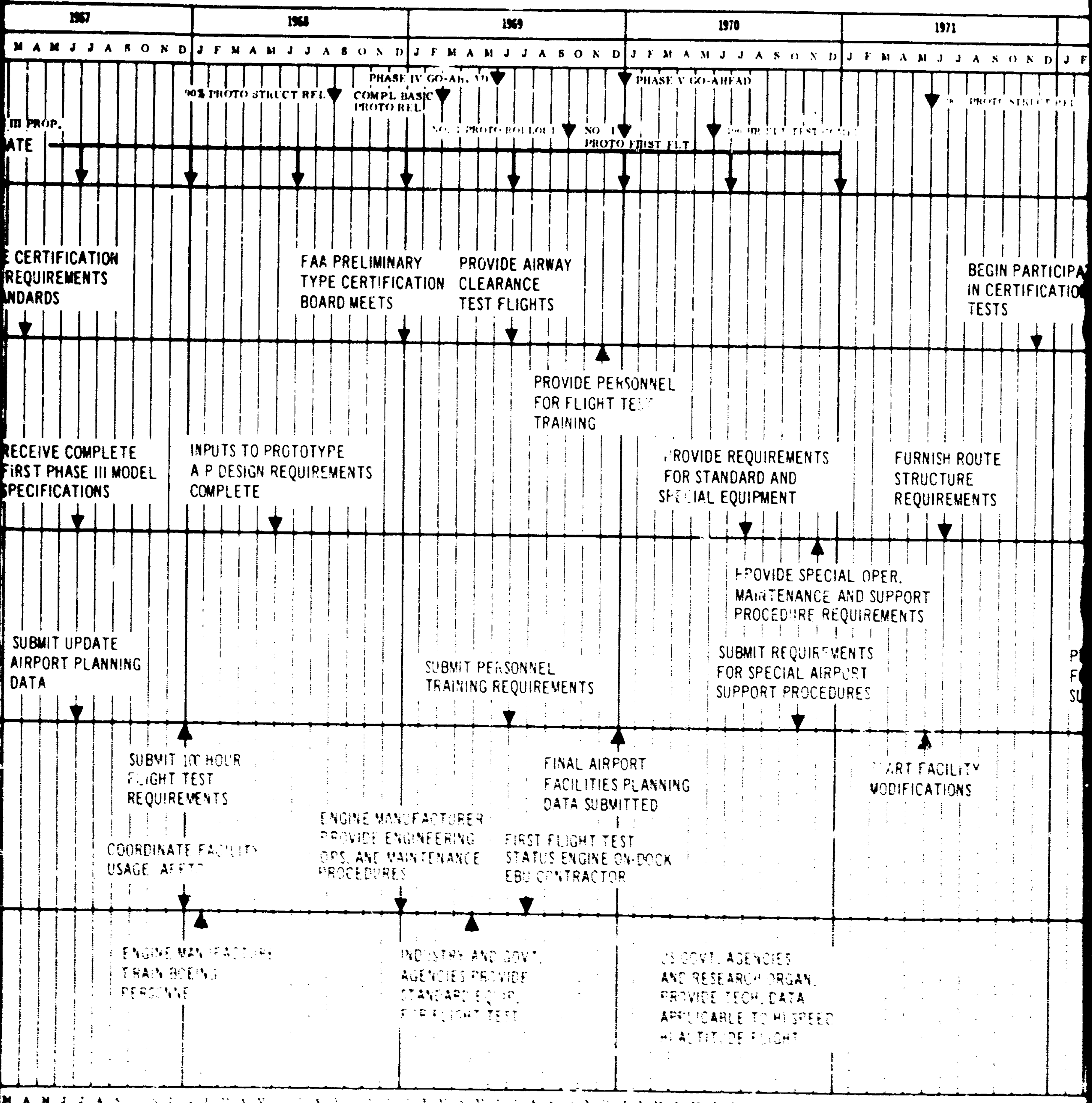
START PHASE II C
PHASE III GO-AHEAD
MAJOR MILESTONES
SUBMIT PHASE III PROP.
OPERATIONAL INTEGRATION PLAN UPDATE
(SEE FIGURE 5.7-1 FOR DETAIL)
BOEING
PROVIDE CERTIFICATION FLIGHT REQUIREMENTS AND STANDARDS
FAA
RECEIVE COMPLETE FIRST PHASE III MODEL SPECIFICATIONS
AIRLINES
SUBMIT UPDATE AIRPORT PLANNING DATA
AIRPORT OPERATORS
ENGINE MANUFACTURER, OTHER GOVERNMENT AND INDUSTRY AGENCIES

H

B-2707 OPERATIONAL PROGRAM PHASING INTERFACES



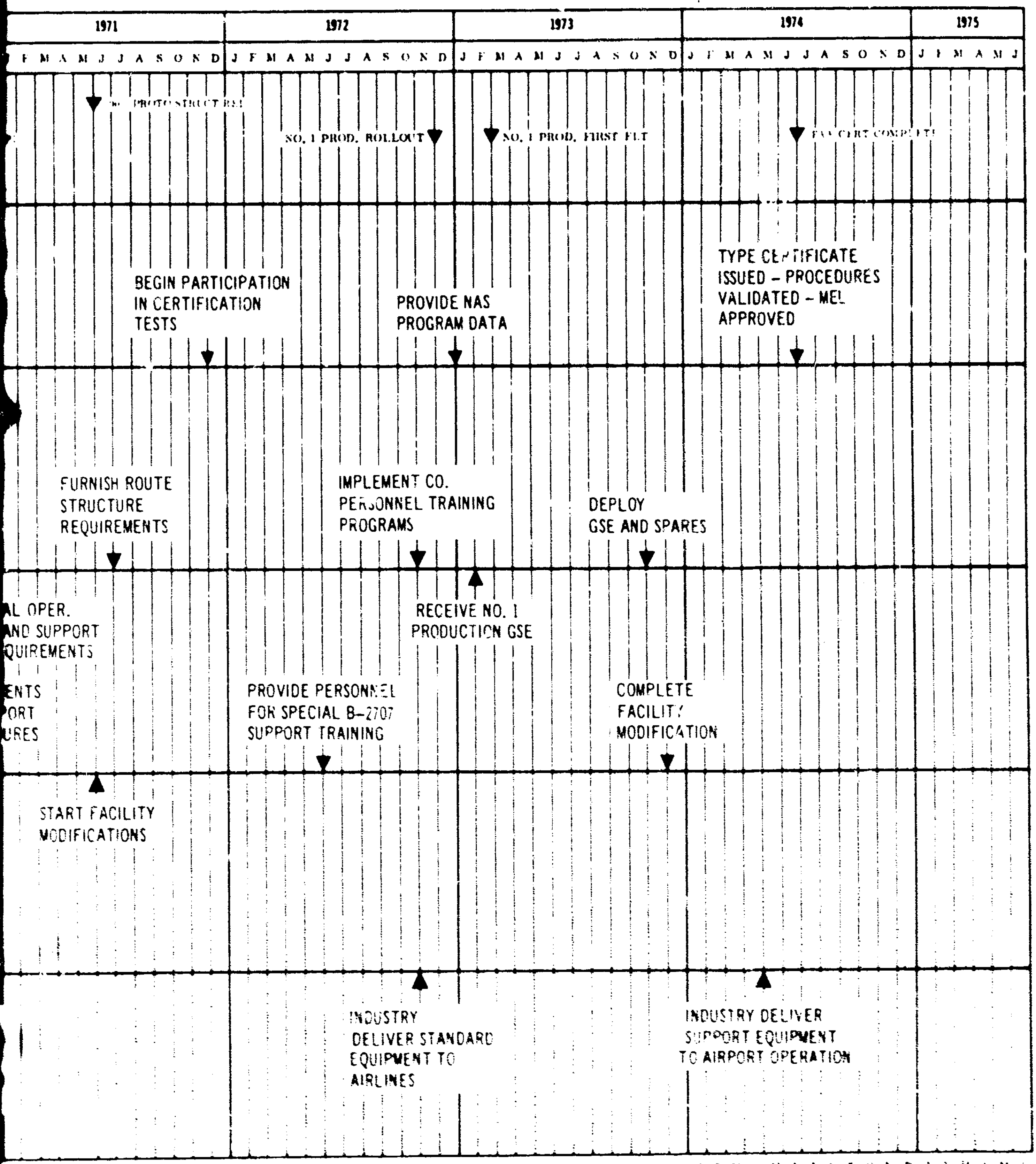


Figure 5–18. B–2707 Operational Program Phasing Interfaces

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LIST OF ABBREVIATIONS AND ACRONYMS

AASHO	American Association of State Highway Officials
A/C	Aircraft
ADF	Automatic direction finder
ADI	Attitude director indicator
AFFTC	Air Force Flight Test Center
AIDS	Aircraft integrated data system
AOG	Aircraft-on-the-ground
ARINC	Aeronautical Radio, Inc.
ARTCC	Air Route Traffic Control Center
ATC	Air traffic control
ATCRBS	ATC radar beacon system
CAS	Calibrated air speed
CAT	Clear air turbulence
CBR	California Bearing Ratio
CDR	Critical design review
CEP	Circular error probability
C_L	Lift coefficient
C_R	Wing reference chord
DEP/APP	Departure/approved
DME	Distance measuring equipment
ESSA	Environmental Sciences Services Admin.
FAR	Federal aviation regulation
FDSIS	Flight deck systems integration simulator
HDI	Horizontal deviation indicator
ICAO	International Civil Aviation Organizations
IFR	Instrument flight rules
ILS	Instrument landing system
I-NAV	Inertial navigation
K_n	Knots, nautical miles/hour
LORAN	Long-range navigation
MEL	Minimum Equipment List
M_{MO}	Maximum operating mach number
NAS	National Airspace System
ΔP	Sonic boom overpressure, pounds per square foot
PNdb	Perceived noise in decibels
REM	Roentgens per equivalent man
RVR	Runway visibility restriction
SAE	Society of Automotive Engineers
SAS	Stability augmentation system
SATCOM	Satellite Communications
SEC	Secondary emission conduction
TAS	True airspeed
T_{MO}	Maximum operating temperature
U_{DE}	Derived gust velocity
VGH	Defined in text
V_2	Airspeed at 35 foot height, during 35 foot height, during 3 engine takeoff
V_B	Speed for Maximum Intensity Gust
V_C	Cruising speed
V_D	Drive speed
V_I	Critical engine failure speed
V_{LOF}	Liftoff airspeed
V_{MCA}	Minimum control speed - air
V_{MCG}	Minimum control speed - ground
V_{MD}	Maximum operating speed
V_{MO}	Maximum operating airspeed
VOR	VHF Omni-Range
VOR/DME	Visual Omni-Range/distance measuring equipment
VORTAC	VHF Omni-Range, Tactical
V_R	Rotation airspeed
V_S	Stall airspeed
V - n	Speed, load factor

ADDENDUM

SUMMARY REPORT - 8 AUGUST 1966 ENGINE PERFORMANCE DATA

The foregoing document is based upon engine performance data received prior to 15 July 1966.

Because there was insufficient time available to completely revise the B-2707 performance after receiving the 8 August 1966 firm technical engine data, the following summary is provided to show the major effect of the firm data on the airplane performance shown in the Phase III proposal documents. Only the most important figures have been provided herein.

If additional or supplemental data is needed, a request to The Boeing Company, SST Division, will receive immediate attention.

ADDENDUM

OPERATIONS SUITABILITY

CONTENTS

SECTION 1.0
INTRODUCTION AND SUMMARY

The Boeing SST Proposal is prepared on the basis of engine manufacturer technical data received prior to July 15, 1966. On August 8, 1966, firm technical data was received from General Electric and Pratt & Whitney Aircraft which differed in some respects from the data received prior to July 15, 1966. The purpose of this addendum is to describe the significant differences and to summarize effects on performance of the Boeing Model 2707 airplane.

All information in the proposal is based on the July 15, 1966 engine data with the exception of the Phase III Proposal Summary, V1-B2707-1, Propulsion Report - Part C, Engine Evaluation, V2-B2707-14, and this addendum. These documents are based on engine data received from the engine manufacturers as of August 8, 1966.

1.1 ENGINE DIFFERENCES

The General Electric GE4/J5P engine data received on August 8, 1966, provided lower airport and community noise levels for all engine operating conditions. These lower noise levels were the result of redesign of the exhaust nozzle and noise suppression data obtained from J-93 engine testing. Acoustic data provided by General Electric also indicated reduced turbine noise from that being predicted by Boeing for the GE4/J5P engine. These changes provide significantly improved takeoff and approach noise for the B-2707 (GE). An improvement in transonic thrust was also provided. Updated installed engine weight, including optional equipment has resulted in a 112-lb weight increase for the GE4/J5P engine installation. Engine changes have not affected the installed pod configuration.

In the case of Pratt & Whitney Aircraft JTF17A-21B engine, a 2-percent reduction in specific fuel consumption (SFC) at essentially all operating conditions was the principal change. This improvement reduces B-2707 (P&WA) fuel consumed over the design mission and lowers the reserve fuel requirements. Updated installed engine weight including optional equipment has resulted in a 190-lb weight increase for the JTF17A-21B engine installation. Engine changes have not affected the installed pod configuration.

1.2 AIRPLANE PERFORMANCE

The major effects of these engine changes on airplane performance are summarized in Table 1-A for the international B-2707 with a maximum design taxi weight of 675,000 lb and in Table 1-B for the domestic airplane with a maximum design taxi weight of 575,000 lb. The improved hot day range capability and noise characteristics of the B-2707 (GE) are apparent, as is the improved range capability of the B-2707 (P&WA).

Table 1-A. Performance Changes International Mission

Maximum Taxi Gross Weight = 675,000 lb		B-2707 (GE)		B-2707 (P&WA)	
		July 15, 1966 Basis	Aug. 8, 1966 Basis	July 15, 1966 Basis	Aug. 8, 1966 Basis
Operational Empty Weight lb		287,500	287,500	285,000	285,760
Range with 50,000 lb Payload					
$\Delta P_{max} = 2.5$ psf					
Standard Day, n mi		3,819	3,819	3,738	3,808
Standard Day + 10°C, nmi		3,471	3,580	3,470	3,547
M_{MO} Climb					
Standard Day, nmi		3,950	3.928	3,882	3,970
M = 0.85 Cruise					
Standard Day, nmi		3,286	3,286	3,870	3,950
Takeoff Noise, PNdb Maximum Augmented Thrust					
Standard Day	Airport Noise	121	117	117	117
	Community Noise cg at 0.595 C_R cg at 0.615 C_R	 100 99	 96 95	 105 104	 105 104
Standard Day + 15°C	Airport Noise	121	117	117	117
	Community Noise cg at 0.595 C_R	 105	 102	 110	 110
Landing Approach Noise, PNdB Standard Day					
Landing Weight, lb		430,000	430,000	420,000	420,000
20°/40° Flaps	cg at 0.595 C_R	112	105	115	115
	cg at 0.615 C_R	111	103	114	114
30°/50° Flaps	cg at 0.615 C_R	113	107	116	116
Decelerating Approach		108	98	111	111

Table 1-B. Performance Changes, Domestic Mission

		Domestic B-2707 (GE)		Domestic B-2707 (P&WA)	
Maximum Taxi Gross Weight = 575,000 lb		July 15, 1966 Basis	Aug. 8, 1966 Basis	July 15, 1966 Basis	Aug. 8, 1966 Basis
Operational Empty Weight lb		275,500	275,500	273,000	273,760
Range with 50,000 lb Payload					
ΔP_{max} = 2.0 psf Climb; 1.5 psf Cruise					
Standard Day, nmi		2,450	2,465	2,442	2,493
Standard Day + 10°C, nmi		2,295	2,368	2,268	2,307
M = 0.85 Cruise					
Standard Day, nmi		2,571	2,571	3,042	3,100
Takeoff Noise, PNdb		Maximum Dry Thrust		80% Maximum Aug. Thrust	
Standard Day	Airport Noise	117	115	114	114
	Community Noise cg at 0.595 C_R	99	93	103	103
	cg at 0.615 C_R	98	92	102	102
Standard Day + 15°C	Airport Noise	116	114	114	114
	Community Noise cg at 0.595 C_R	107	99	108	108
Landing Approach Noise, PNdB Standard Day					
Landing Weight, lb		410,000	410,000	400,000	400,000
20°/40° Flaps	cg at 0.595 C_R	112	104	115	115
	cg at 0.615 C_R	110	102	114	114
30°/50° Flaps	cg at 0.615 C_R	112	106	116	116
Decelerating Approach		108	98	111	111

SECTION 2.0
ENGINE CHANGES

2.1 PERFORMANCE

2.1.1 General Electric GE4/J5P Engine

A 6-percent improvement in transonic thrust was provided as well as increased transonic hot day thrust by means of higher engine rpm and increased airflow for an incremental 50-lb weight increase. Figure 2-1 shows the change in hot day transonic thrust for a 2.5 PSF sonic boom overpressure climb path. Reduced transonic inlet drag due to lower bypass airflow is also shown.

2.1.2 Pratt & Whitney Aircraft JTF17A-21B Engine

The two percent SFC reduction for the JTF17A-21B engine at all power settings except idle power is listed in Table 2-A for important B-2707 operating points. This improvement is provided as a result of increased component efficiencies demonstrated in primary burner, duct burner, and nozzle component development programs.

2.2 INSTALLATION

Pod configuration and external contours for both engine installations are unchanged. The final installed pod weights for both engines including added weight for optional equipment are listed in Table 2-B.

2.3 NOISE

The noise characteristics of the JTF17A-21B remain unchanged from those data presented in the body of the Boeing SST proposal. The remainder of the discussion concerns the GE4/J5P engine.

2.3.1 Engine Noise Characteristics GE4/J5P

The engine noise characteristics of the GE4/J5P engine have been predicted from the engine data and jet noise suppression as supplied by General Electric. Additional engine noise suppression achieved through inlet choking by use of the sonic throat principle as described in the Airport and Community Noise Program report, V4-B2707-4, has also been included. The jet noise suppression values used in the calculation of noise levels for the GE4/J5P engine are shown in Fig. 2-2. These values have been determined by General Electric through acoustic tests that have been conducted on a J-93 engine.

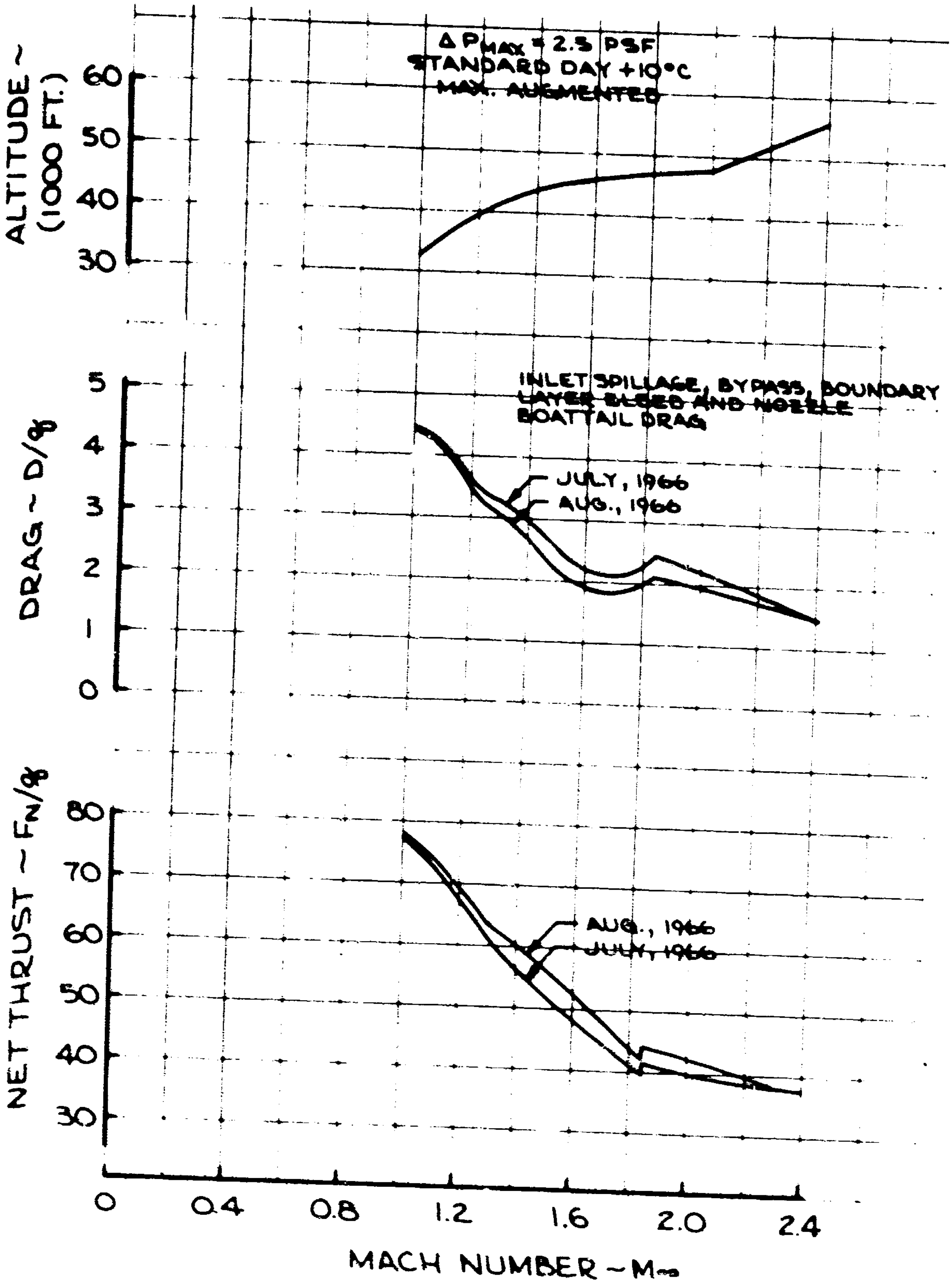


Figure 2-1. GE4 JSP Climb Performance, Standard Day + 10°C

Table 2-A. JTF17A-21B Performance Summary

Power Setting	Pressure Altitude ft	Temperature	Mach No	Net Thrust lb	July-1966 SFC lb/hr/lb	August-1966 SFC lb/hr/lb
Max Augmented	0	Std	0	56,740	1.86	1.83
Max Non-Augmented	0	Std	0	35,490	0.77	0.76
Max Augmented	45,000	Std	1.2	19,630	1.94	1.90
Max Augmented	45,000	Std + 10°C	1.2	18,140	2.00	1.96
Partial Augmented	65,000	Std	2.7	15,000	1.57	1.54
Partial Augmented	65,000	Std + 10°C	2.61	15,000	1.66	1.63
Partial Non-Augmented	36,150	Std	0.85	5,000	1.07	1.06
Partial Non-Augmented	15,000	Std	0.5	5,000	1.10	1.08

2.3.1 (Continued)

The unsuppressed noise levels for the GE4/J5P engine for ground and flight operations are shown in Figs. 2-3 and 2-4. Also shown in these figures are the predicted noise levels with all suppression included. The effect of the open-nozzle concept wherein the nozzle throat area is maintained on a maximum area schedule is included in the suppressed noise level predictions. The predicted noise spectra for a series of engine operating conditions have also been predicted and are presented in Table 2-C.

Noise levels beneath and to the side of the airplane flight path have been determined from the revised noise data. These levels have been integrated into contours of Perceived Noise Level for takeoff. These contours are shown for the B-2707 (GE) international airplane in Fig. 4-12 and the B-2707 (GE) domestic airplane in Fig. 4-14.

The landing noise characteristics of the B-2707 (GE) have changed significantly due to the noise data presented on August 8, 1966. These data indicated that turbine noise would not contribute significantly to the total noise from the airplane even at landing approach power settings. Boeing had been predicting very significant noise increases due to turbine noise contribution. The predictions were based on the J-75 engine acoustic test results. Since the GE data were obtained on an engine more closely resembling the SST turbojet offering, these data should be more representative of the noise characteristics of the SST engine. Therefore the B-2707 landing noise levels have been revised to conform to the August 8, 1966 data inputs. The results of these revisions are shown in Figs. 4-17 and 4-18.

Table 2-B. Installed Pod Weight

	B-2707 (GE)	B-2707 (P&WA)
Engine weight	11,125	9,910
Optional equipment	112	730
Total	11,237	10,640
Inlet	2,070	2,485
Cowl panels		
Forward	325	225
Aft	150	---
Structure	495	480
Miscellaneous	35	35
Total	14,312	13,865

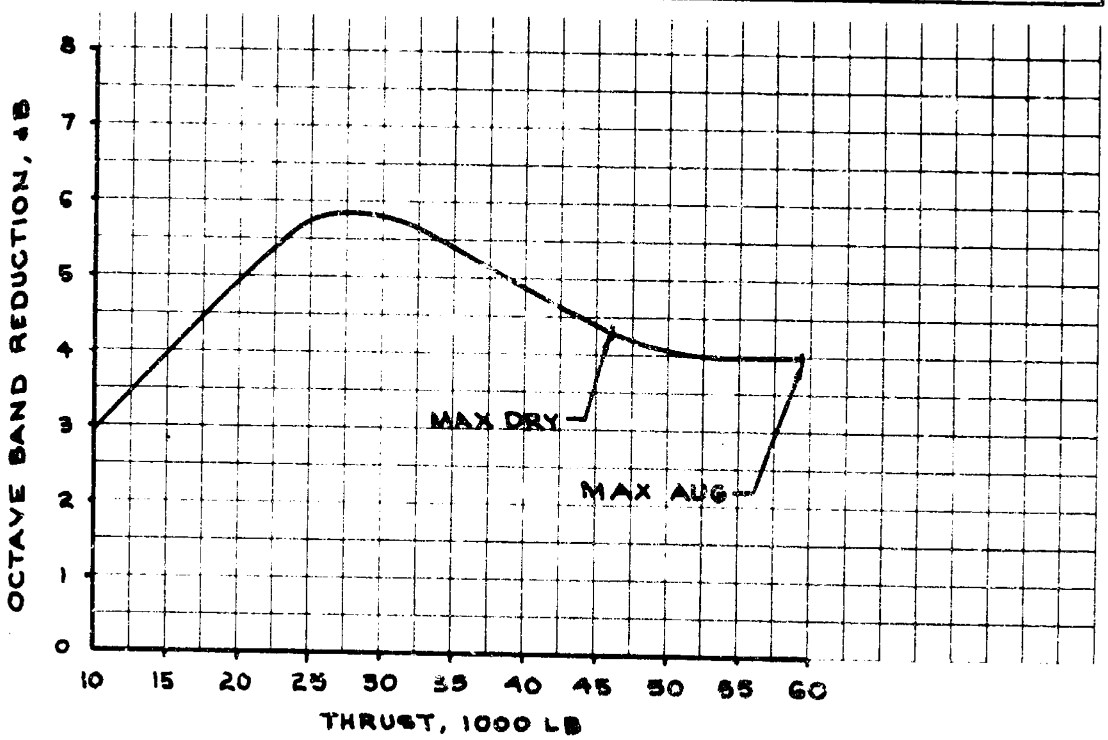


Figure 2-2. Predicted GE4/J5P Jet Noise Suppression

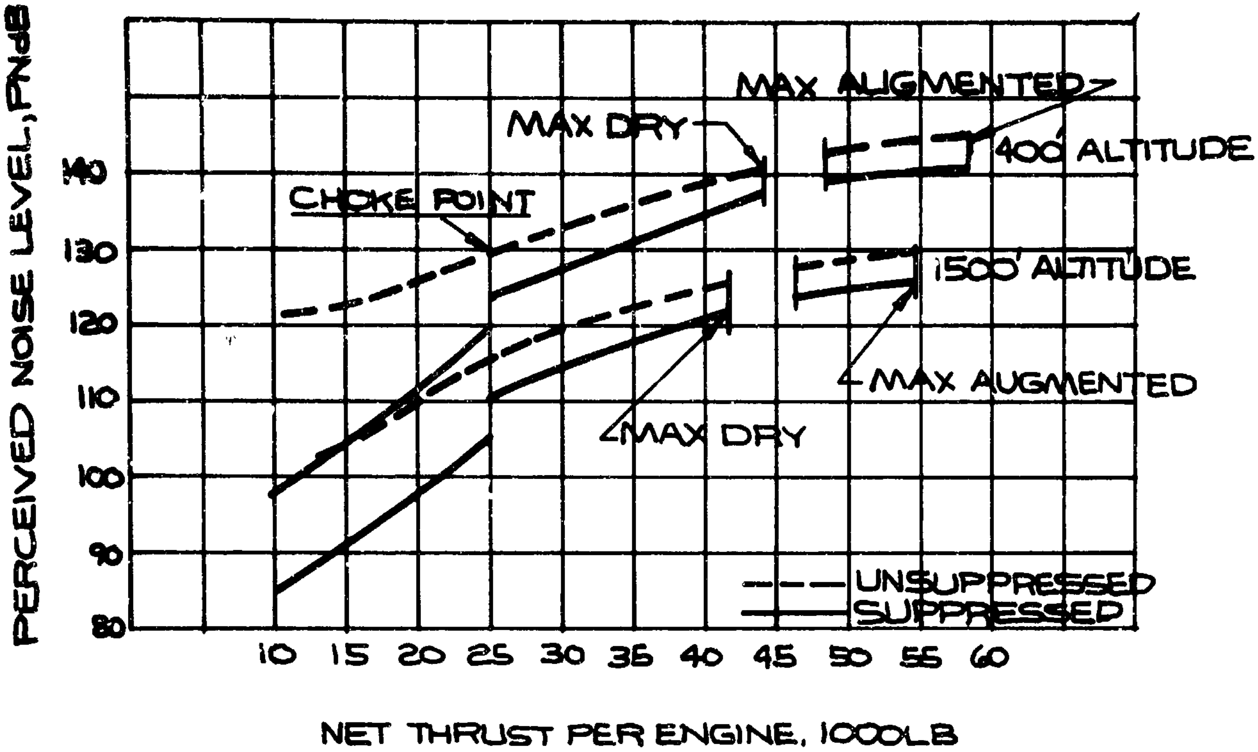


Figure 2-3. Inflight Noise Characteristics of GE4/J5P Engines

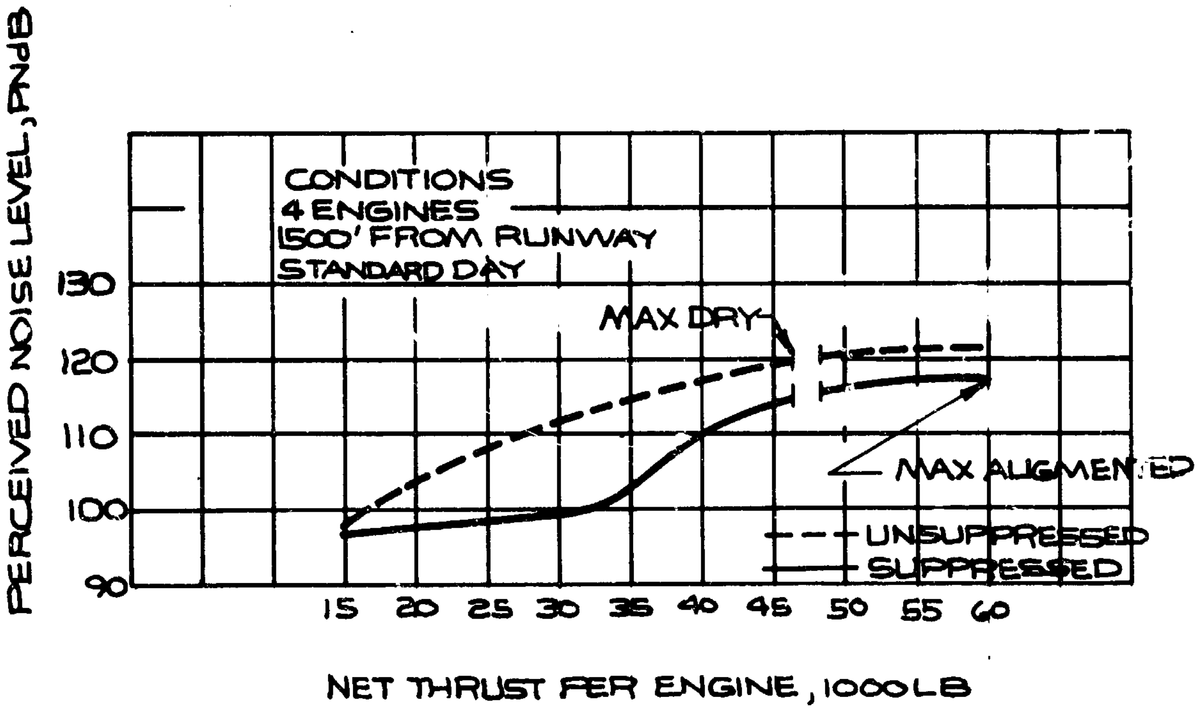


Figure 2-4. Noise Characteristics of GE4/J5P Engines For Static Ground Operations

Table 2–C. Noise Spectra For GE4/J5P Engine

Operating Conditions (4 Engines)	Overall SPL	Octave Band Sound Pressure Level – (db) 1	2	3	4	5	6		7		8		Perceived Noise
	(dB)	Jet	Jet	Jet	Jet	Jet	Jet	Comp	Jet	Comp	Jet	Comp	(PNdB)
Ground Static - 1,500 Ft													
Max Aug - Unsuppressed	118.5	113	115	113	109	102	92	75	78	44	61	62	121.0
- Suppressed	114.5	109	111	109	105	98	88	75	74	74	57	62	117.0
Max Dry - Unsuppressed	117.0	111	113	111	107	100	90	75	76	74	60	62	119.0
- Suppressed	113.0	107	109	106	103	98	86	75	72	74	56	62	114.5
Taxi (5,000 lb/Fn) - 200 Ft													
- Unsuppressed	106.0	85	85	82	80	75	70	101	65	102	60	100	119.0
- Suppressed	97.0	85	85	82	80	75	70	91	65	92	60	90	111.0
Flight (0.3 M) - 1,500 Ft Alt													
Max Aug - Unsuppressed	125.5	113	118	121	118	114	108	87	95	86	77	74	130
- Suppressed	121.0	109	114	117	114	110	104	87	91	86	73	74	126
Max Dry - Unsuppressed	122.0	110	116	117	115	111	104	87	90	86	73	74	126.5
- Suppressed	118.0	106	112	112	111	107	100	87	86	86	69	74	112.0
18,500 lb/Fn - Unsuppressed	99.0	93	94	93	89	83	75	86	61	85	44	75	107
- Suppressed	95.0	89	90	89	84	73	70	61	61	60	43	50	97
15,700 lb/Fn - Unsuppressed	96.0	90	91	90	85	80	72	82	58	81	41	68	105
- Suppressed	92.5	86	87	86	81	76	68	57	54	56	37	43	94
Landing (0.23 M) - 326 Ft Alt													
- Unsuppressed	111.5	101	100	98	94	89	84	101	79	107	74	103	124
- Suppressed	101.5	97	96	94	90	85	80	77	75	82	70	78	105

SECTION 3.0
AIRPLANE WEIGHT EFFECTS

The Airframe Design Report - Part A, Weight and Balance, gives an Operating Empty Weight breakdown of the GE and P&WA powered airplanes. Table 3-A lists these comparative weights as they are modified by the August 8, 1966 engine data and other related airplane changes.

The 760-lb weight change i[illegible] P&WA powered airplane increases the Manufacturer's Empty Weight, Operating Empty Weight and Zero Fuel Weight of the following P&WA powered airplanes:

a. 635,000-lb gross weight design point airplane

b. 675,000-lb gross weight production international airplane

c. 635,000-lb gross weight prototype airplane

d. 575,000-lb gross weight production domestic airplane

TABLE 3-A
OPERATING EMPTY WEIGHT

GROUP	GE	P&WA
Engines	44,950	42,560
Nacelle	12,300	12,900
Horizontal Tail	20,400	20,460
Engine Accessories - ADS	1,100	1,160
Anti-Icing and Anti-Fogging	280	330
Starting System	400	430
Fuel System	7,400	7,510
Hydraulic System	3,600[1]	3,420
Body Structure	47,300[1]	47,220
Other	149,770	149,770
Operational Empty Weight (Max. design taxi weight 675,000 lb)	287,500	285,760
Original Operating Empty Weight	287,500	285,000
Weight Change	0	+760 lb

[1] Includes effect of ram air turbine - B-2707 (GE) only

SECTION 4.0
AIRPLANE PERFORMANCE

The effect of the changes in engine data on the standard day payload-range capability are illustrated in Fig. 4-1 for the international B-2707 and Fig. 4-2 for the domestic airplane. As noted, there is no significant effect on the standard day range of the B-2707 (GE). The improved specific fuel consumption of the Pratt & Whitney Aircraft engine results in slightly less than 2 percent increase in range. The effect of temperature changes from standard day on range are shown in Fig. 4-3 for the B-2707 (GE) and Fig. 4-4 for the B2707 (P&WA). There is no change for the B-2707 (P&WA) curve since the effect of temperature on the engine data did not change.

Figures 4-5 and 4-6 show the off-loaded supersonic range capability and corresponding transonic thrust margins for the airplanes. The range performance with a mixed subsonic and supersonic mission is shown in Fig. 4-7. Figures 4-8 and 4-9 show fuel, time, and distance breakdowns for a nominal, standard day, intercontinental mission at a maximum sonic-boom overpressure of 2.5 psf for both airplanes.

Summaries of takeoff performance, using maximum augmented thrust, are shown in Figs. 4-10 and 4-11. The significant change in takeoff performance is in the airport and community noise of the B-2707 (GE). The changes in noise characteristics are shown in more detail by the noise contours around the airport in Figs. 4-12 through 4-15.

The noise data shown on the preceding curves are based on the engines as proposed by the engine contractors with the use of a sonic throat in the inlet at reduced powers. With the Boeing noise suppressor, the August 8, 1966 General Electric engine data have resulted in an additional 1 PNdb reduction in the airplane's noise characteristics at maximum augmented thrust. Noise contours with the Boeing jet suppressor are compared in Fig. 4-16 for the B-2707 (GE).

The only change in landing performance for the airplanes caused by the changed engine data is in the approach noise for the B-2707 (GE) as shown in Figs. 4-17 and 4-18. Figure 4-19 shows the B-2707 (P&W) landing performance.

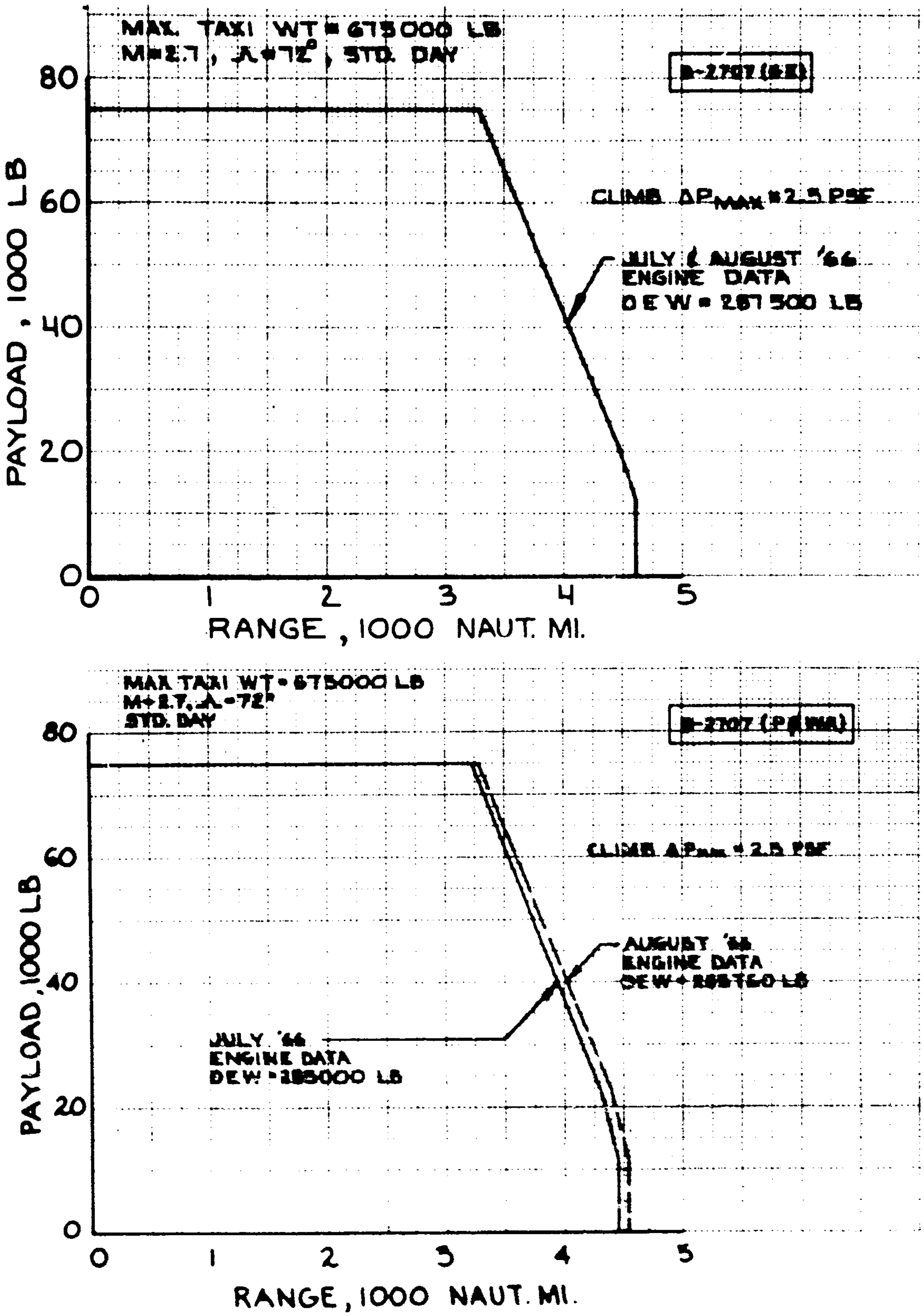
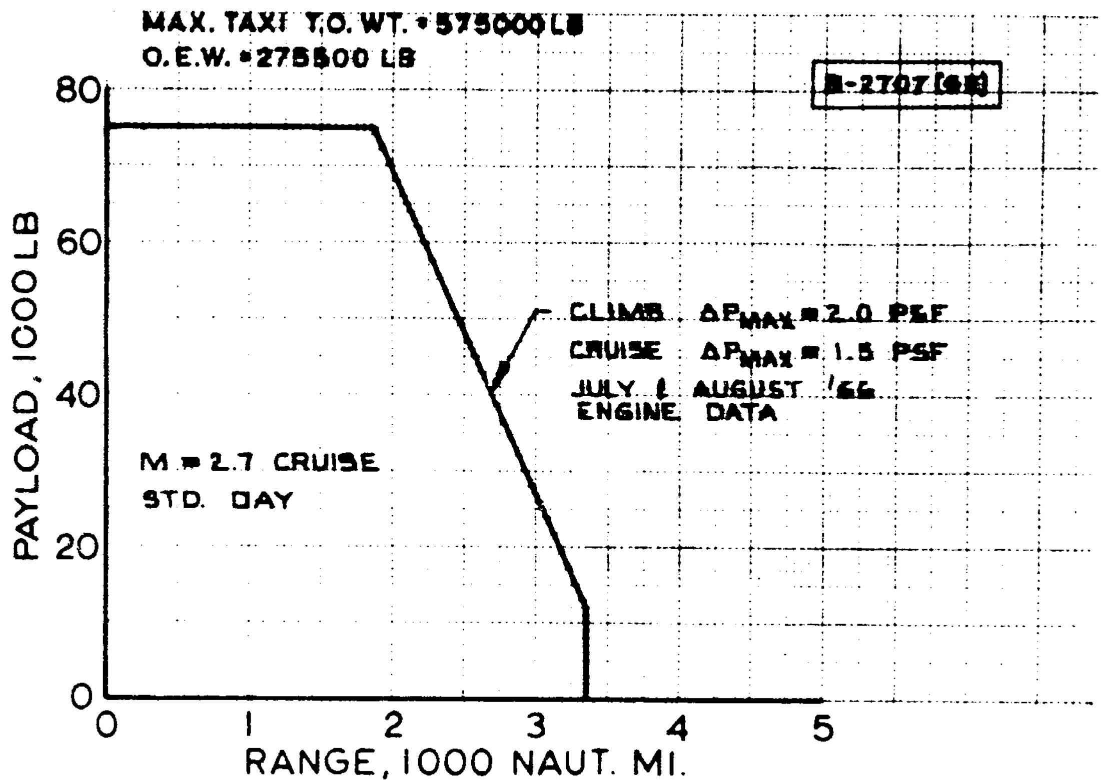


Figure 4-1. Payload-Range, International Model B-2707



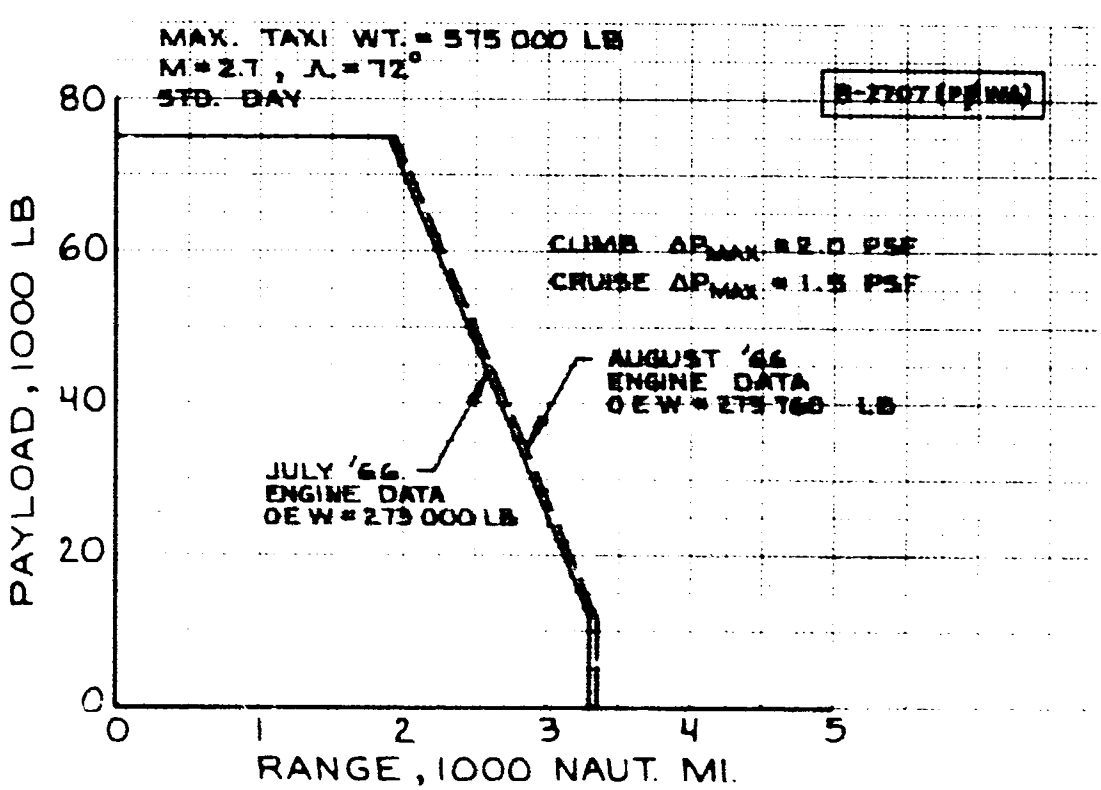


Figure 4-2. Payload-Range, Domestic Model B-2707

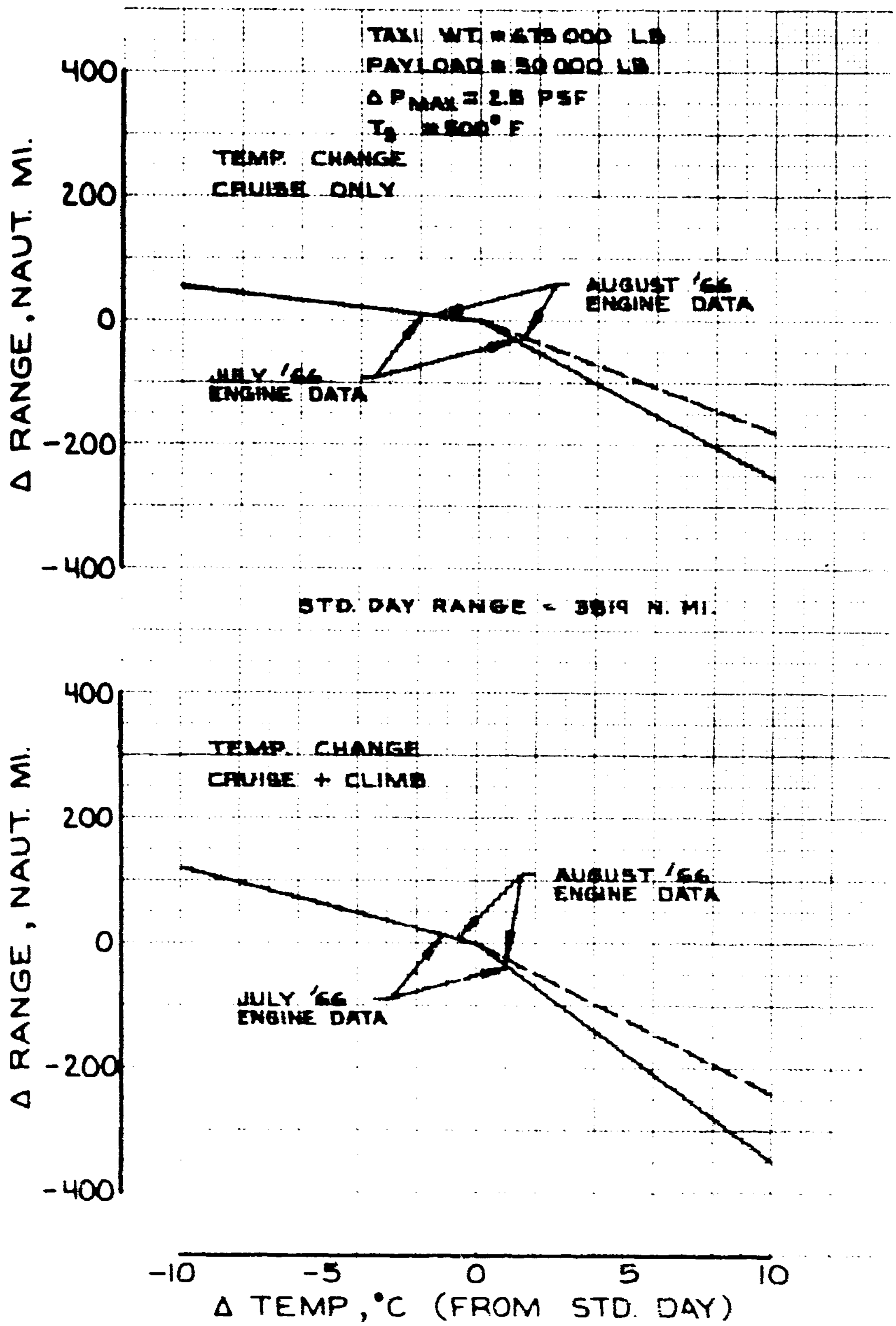


Figure 4-3. Effect of Temperature Change on Range Model B-2707 (GE)

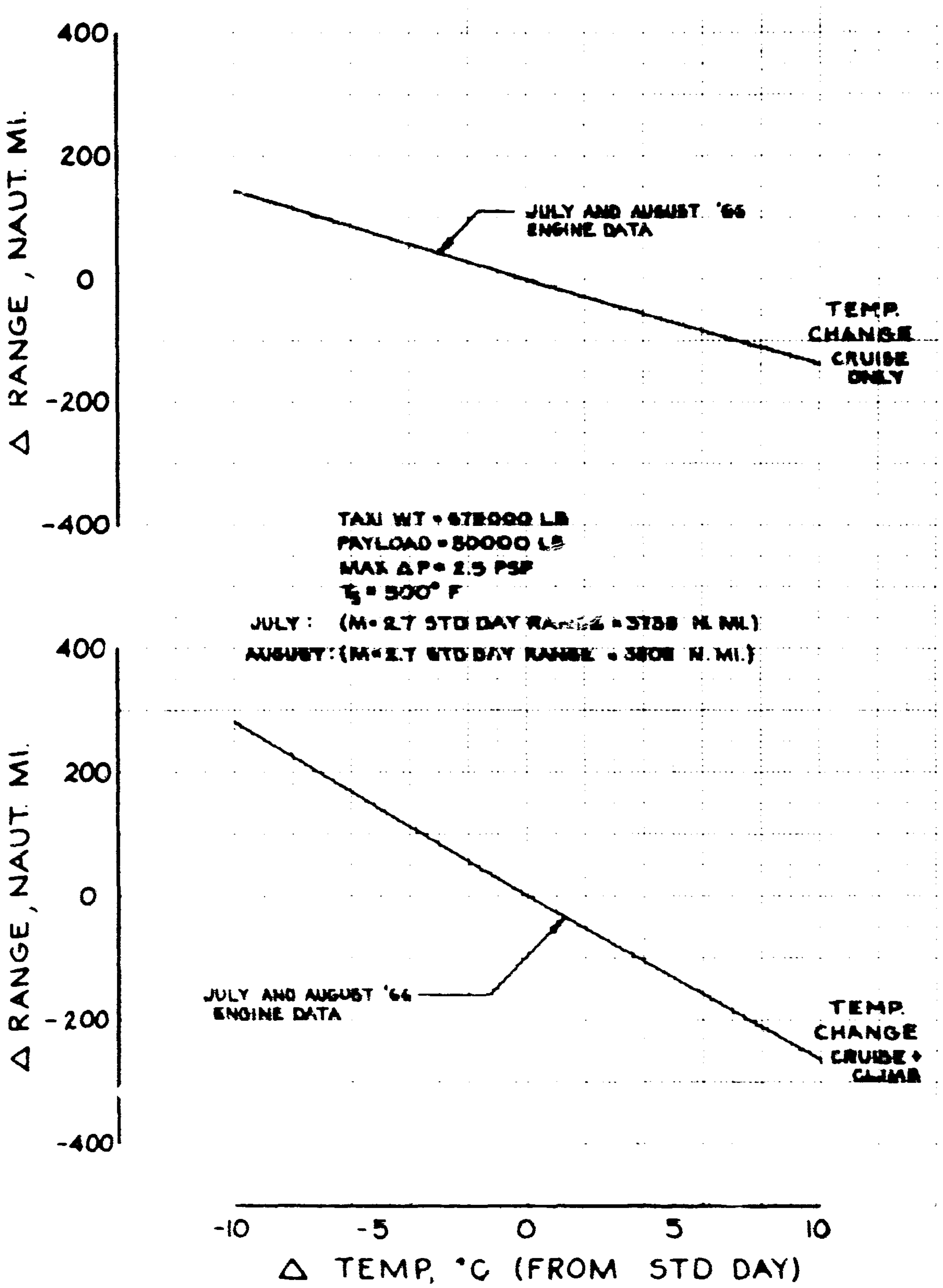


Figure 4-4. Effect of Temperature Change on Range Model B-2707 (P&WA)

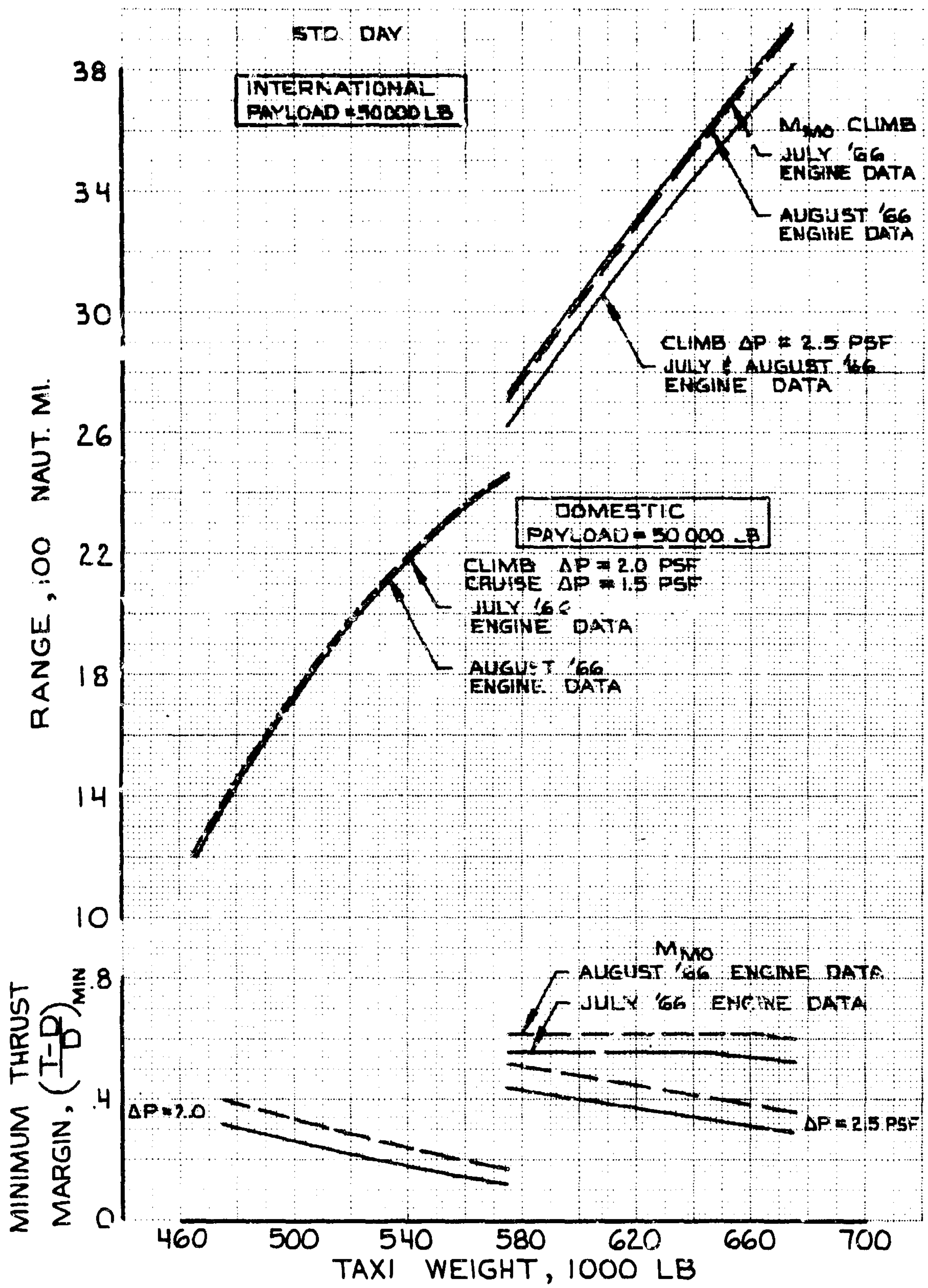


Figure 4-5. Off-Loaded Airplane Performance Model B-2707 (GE)

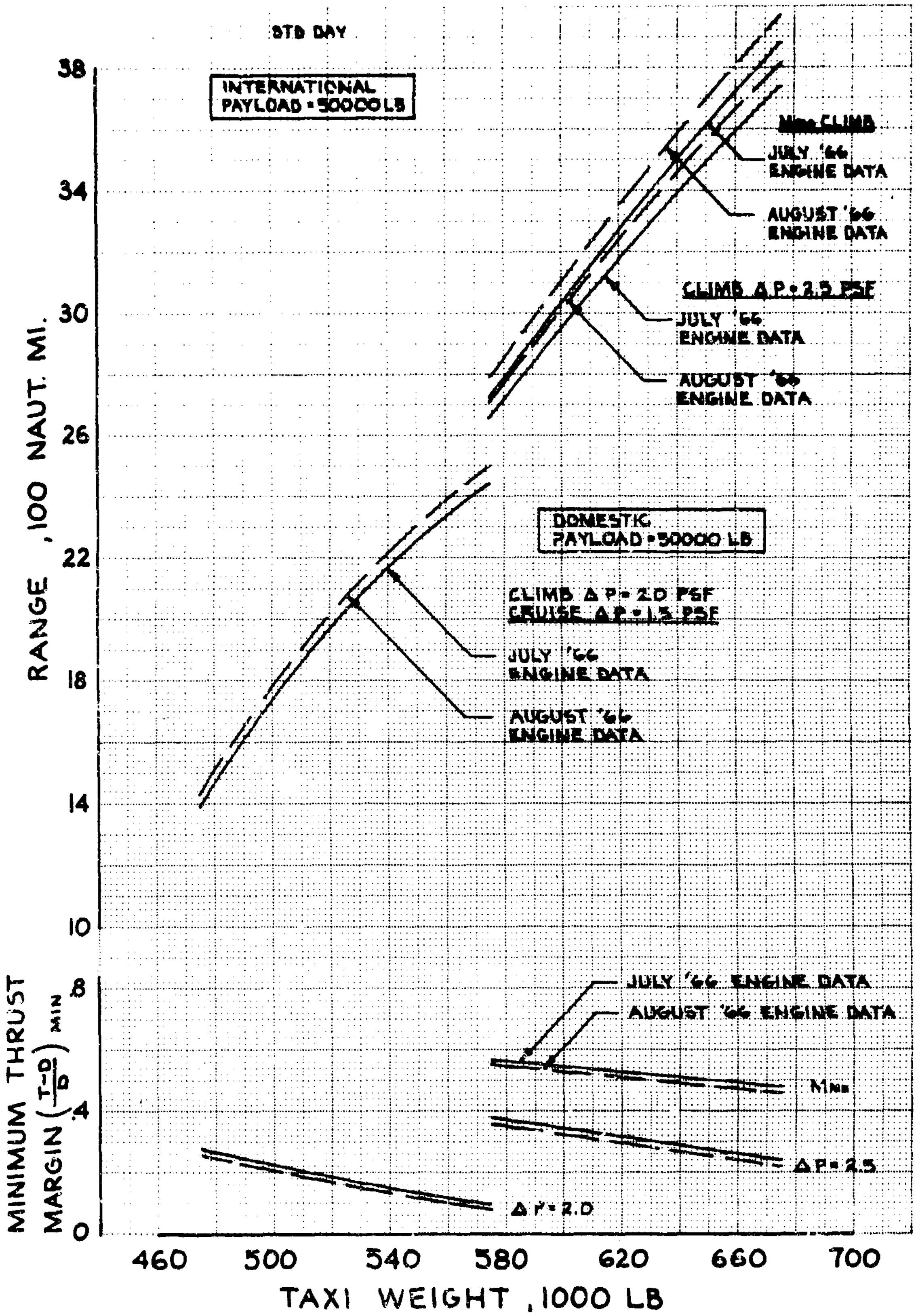
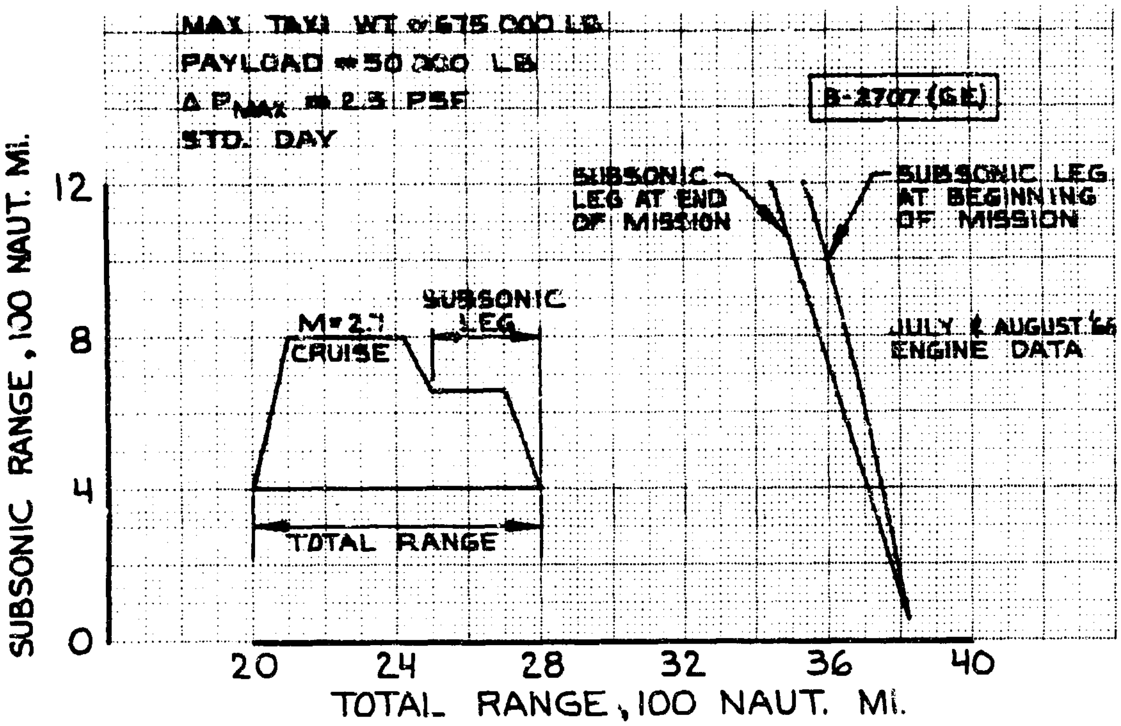


Figure 4-6. Off-Loaded Airplane Performance Model B-2707 (P&WA)



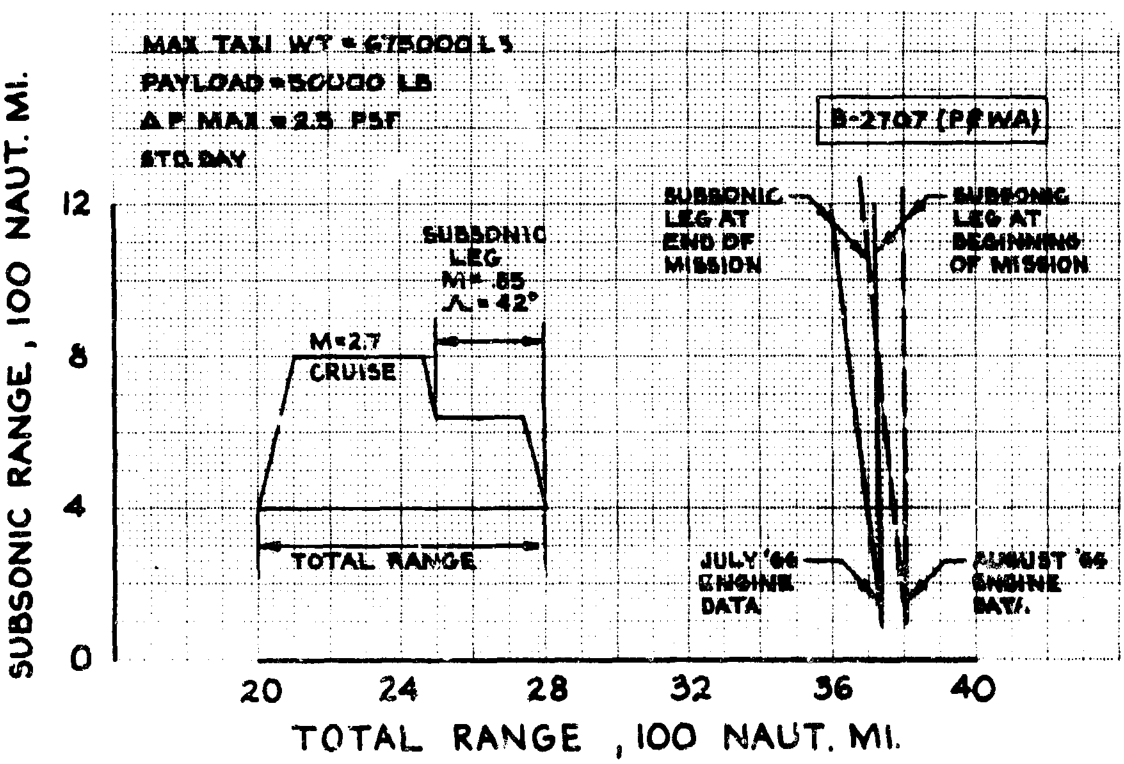
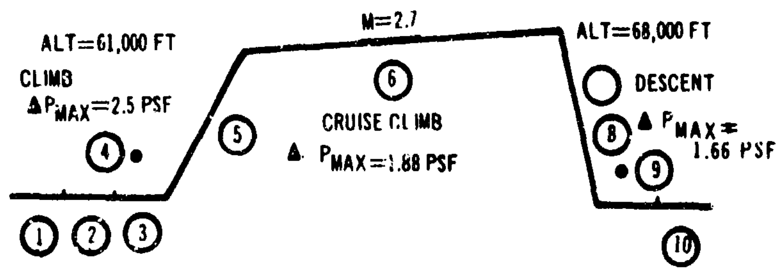


Figure 4-7. Operational Versatility Model B-2707

Max. Design
Taxi Weight 675,000 lb
OEW 287,500 lb
Payload = 50,000 lb
Wing Area = 9,000 ft^2
Engine = GE4/J5P
Airflow 620 lb/sec

Std Day, Zero Wind
Phase III Rules
Block Time = 3.290 hr
Block Fuel = 292,181 lb



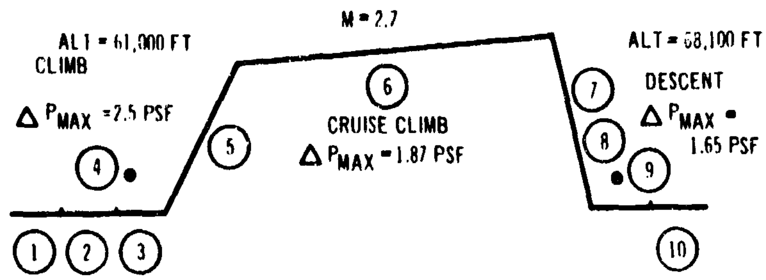
	Fuel Burned (lb)	Fuel Remaining (lb)	Weight At End of Operation (lb)	Time (hr)	Distance (nmi)
1. Taxi-out	4,060	333,440	670,940	0.167	—
2. Takeoff (Sea level to 35 ft)	4,150	329,290	666,790	0.010	—
3. Acceleration to climb speed	4,790	324,500	662,000	0.024	5.0
4. Departure air maneuver allowance (250 kts EAS & 5,000 ft)	4,000	320,500	658,000	0.0673	—
5. Acceleration and climb	81,400	238,800	576,600	0.411	337
6. Supersonic cruise climb	186,791	52,309	389,809	2.112	3271
7. & 8. Deceleration and descent (cruise altitude to 1,500 ft)	2,330	49,979	387,479	0.333	206
9. Destination air maneuver (Approach & Landing Allowance, 250 kts EAS at 5,000 ft) WT = WT at (8) = 5% block fuel	2,940	47,039	384,539	0.083	—
10. Taxi-in	(1,720)*			0.083	—
TOTAL MISSION	290,461			3.290	3819
A. 5 percent block fuel	14,609		369,930		
B. Missed approach (climb sea level to 1,500 ft)	2,510		367,420		
C. Climb from 1,500 ft subsonic cruise, descent to sea level at altn (300 st mi)	20,070		347,350		
D. 20 min hold at 15,000 ft over alternate	9,850		337,500		
TOTAL RESERVES	47,039				
TOTAL FUEL	337,500				

* Fuel burned not included in mission fuel; for D.O.C. only

Figure 4-8 B-2707 (GE) International Supersonic Cruise Mission

Max Design
Taxi Weight 675,000 lb
OEW 285,760 lb
Payload 50,000 lb
Wing Area 9,000 sq ft
Engine PWAJTF17A-21B
W_a 687 lb/sec

Std Day, Zero Wind
Phase III Rules
Block Time 3.400 hr
Block Fuel 297,890 lb



	Fuel Burned (lb)	Fuel Remaining (lb)	Weight At End of Operation (lb)	Time (hr)	Distance (nmi)
1. Taxi-out	2,880	336,360	672,120	0.167	—
2. Takeoff (Sea level to 35 ft)	4,385	331,975	667,735	0.010	—
3. Acceleration to climb speed	4,880	327,095	662,855	0.043	10
4. Departure air maneuver allowance (250 kts EAS & 5,000 ft)	3,160	323,935	659,695	0.067	
5. Acceleration and climb	95,400	228,535	564,295	0.570	422
6. Supersonic cruise climb	181,626	46,909	382,669	2.051	3,180
7. & 8. Deceleration and descent (cruise altitude to 1,500 ft)	2,070	44,839	380,599	0.326	196
9. Destination air maneuver (Approach & Landing Allowance, 250 kts EAS at 5,000 ft) WT = WT at (8) - 5% block fuel	2,234	42,605	378,365	0.083	—
10. Taxi-in	(1,255)*			0.083	—
TOTAL MISSION	296,635			3.400	3,808
Reserves					
A. 5 percent block fuel	14,895		363,470		
B. Missed approach (climb sea level to 1,500 ft)	2,200		361,270		
C. Climb from 1,500 ft subsonic cruise, descend to sea level at altn (300 st mi)	17,670		343,600		
D. 20 min hold at 15,000 ft over alternate	7,840		335,760		
TOTAL RESERVES	42,605				
TOTAL FUEL	339,240				

* Fuel burned not included in mission fuel; for D.O.C. only

Figure 4-9 B-2707 (P&WA) International Supersonic Cruise Mission

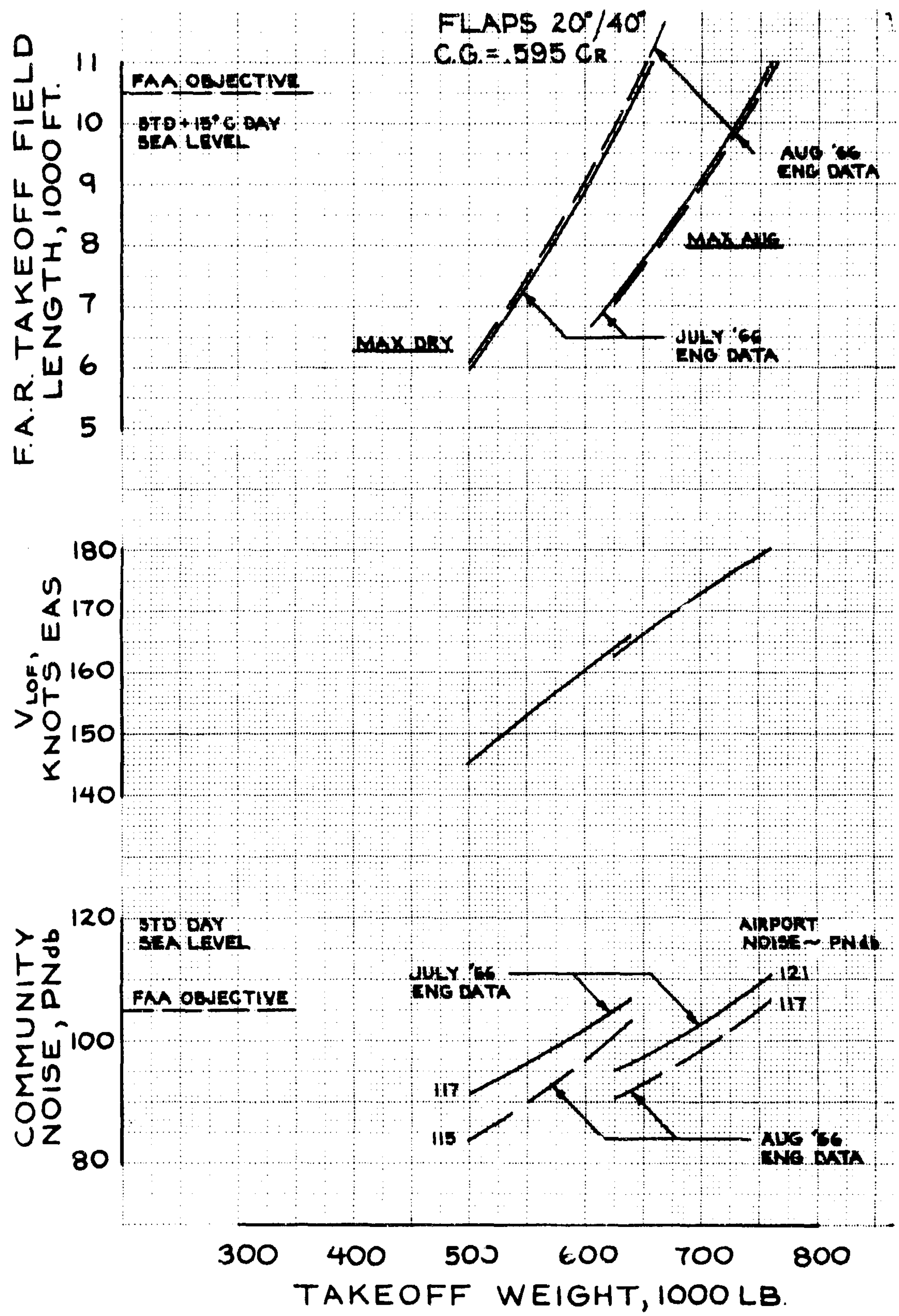


Figure 4–10. Takeoff Performance Model B–2707 (GE)

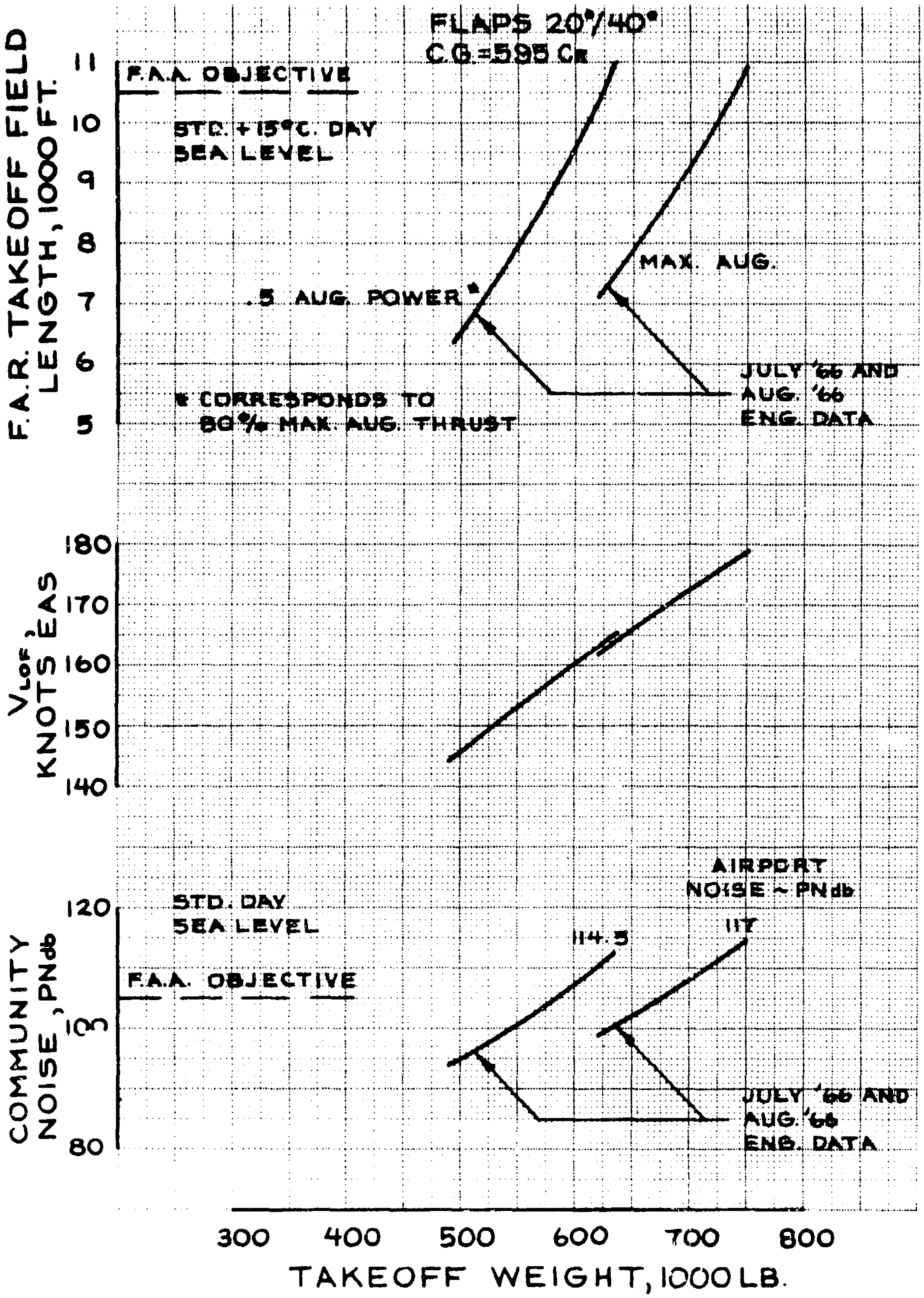


Figure 4-11. Takeoff Performance Model B-2707(P&WA)

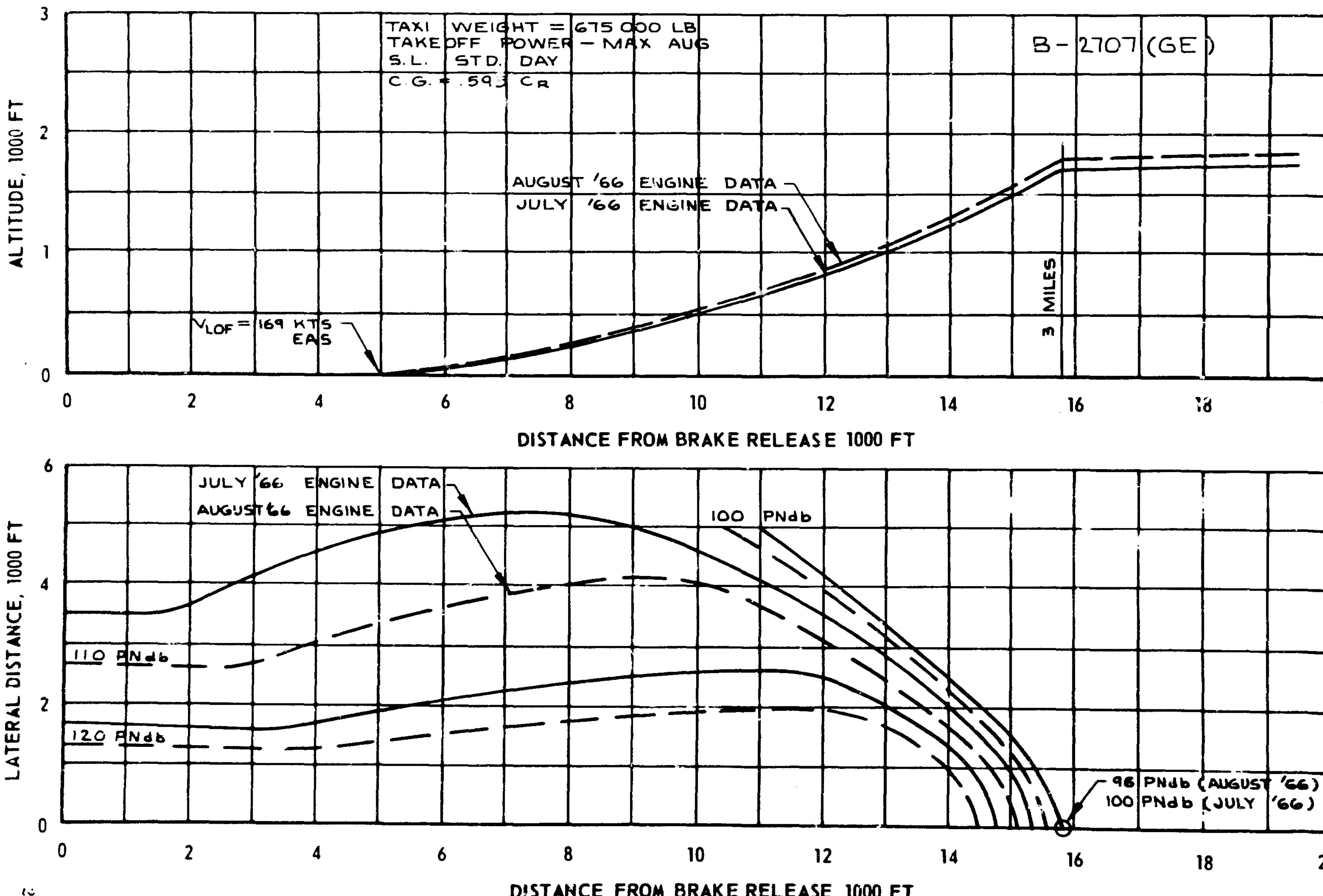


Figure 4-12. Noise Contours, International Mission, Standard Day Model B-2707 (GE)

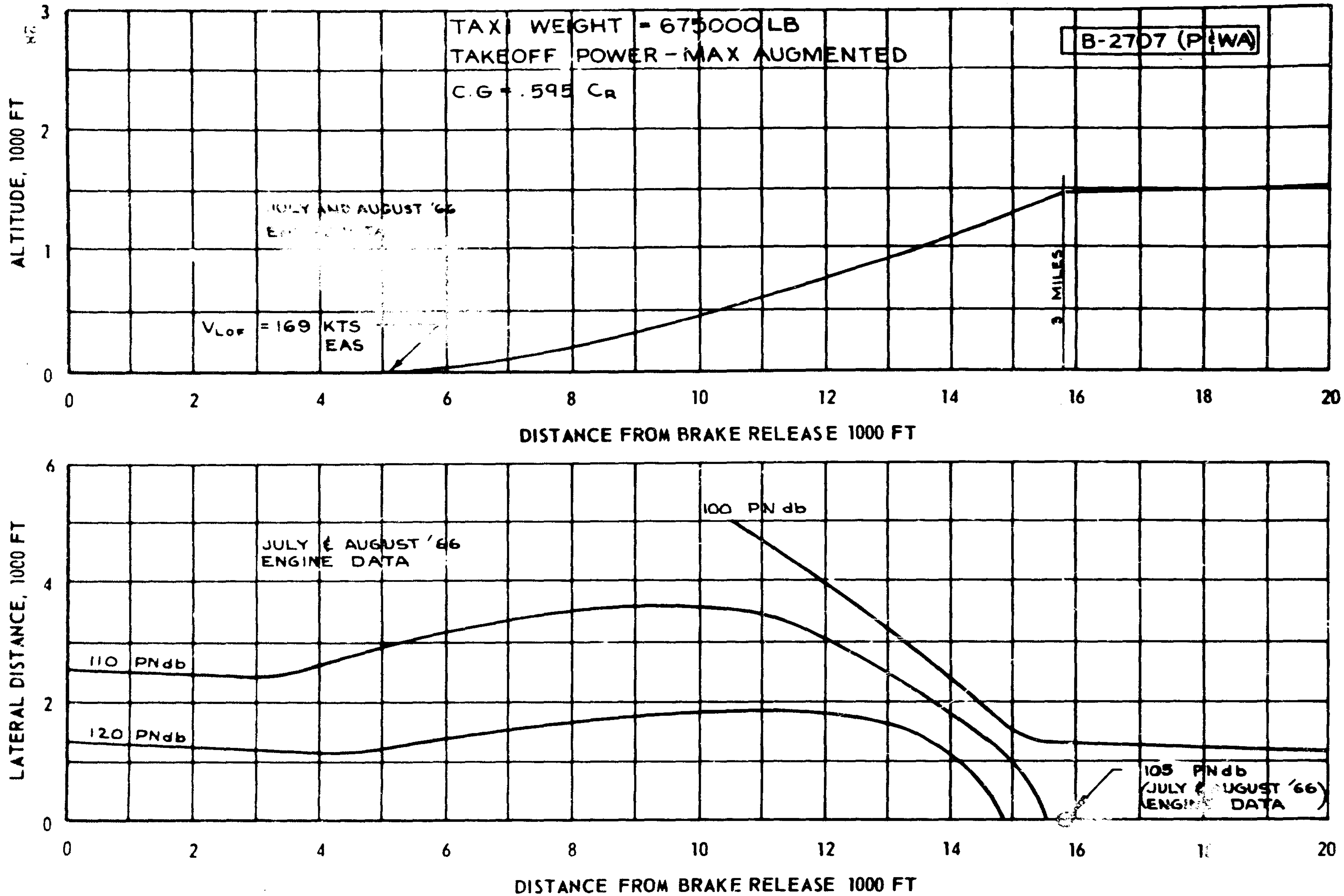


Figure 4–13. Noise Contours, International Mission, Standard Day Model B–2707 (P&WA)

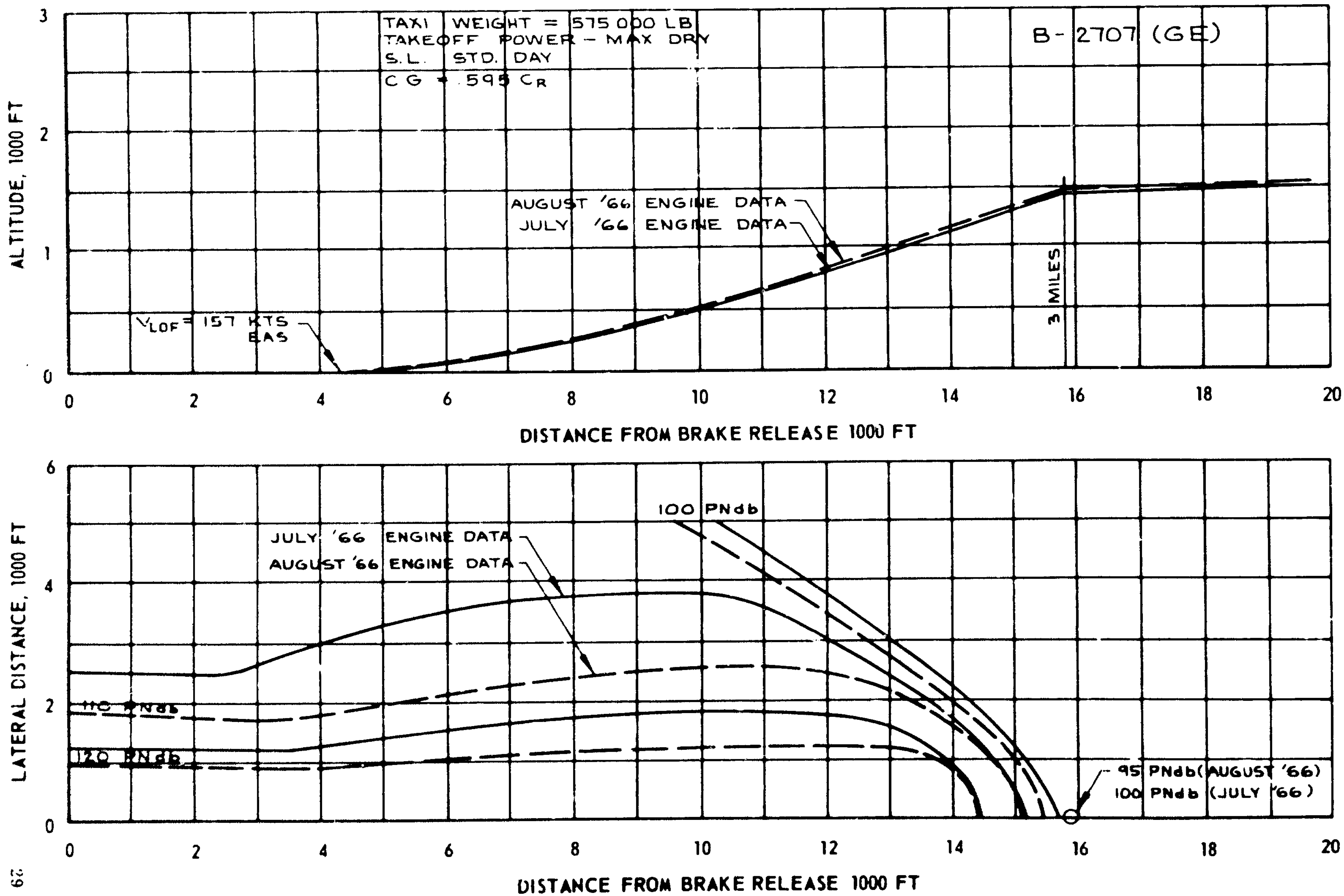


Figure 4–14. Noise Contours, Domestic Mission, Standard Day Model B–2707 (GE)

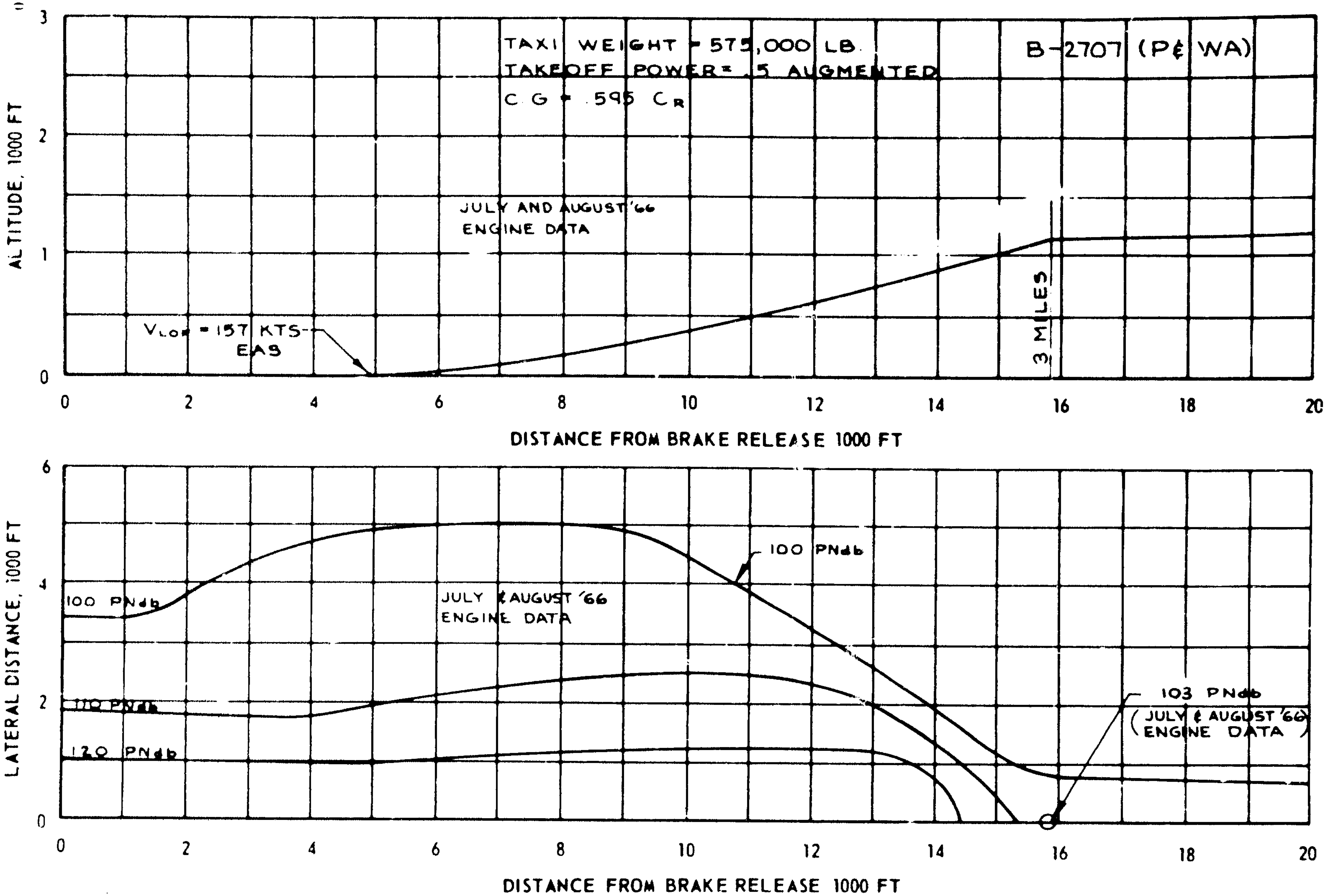


Figure 4-15. Noise Contours, Domestic Mission Standard Day Model B-2707 (P & WA)

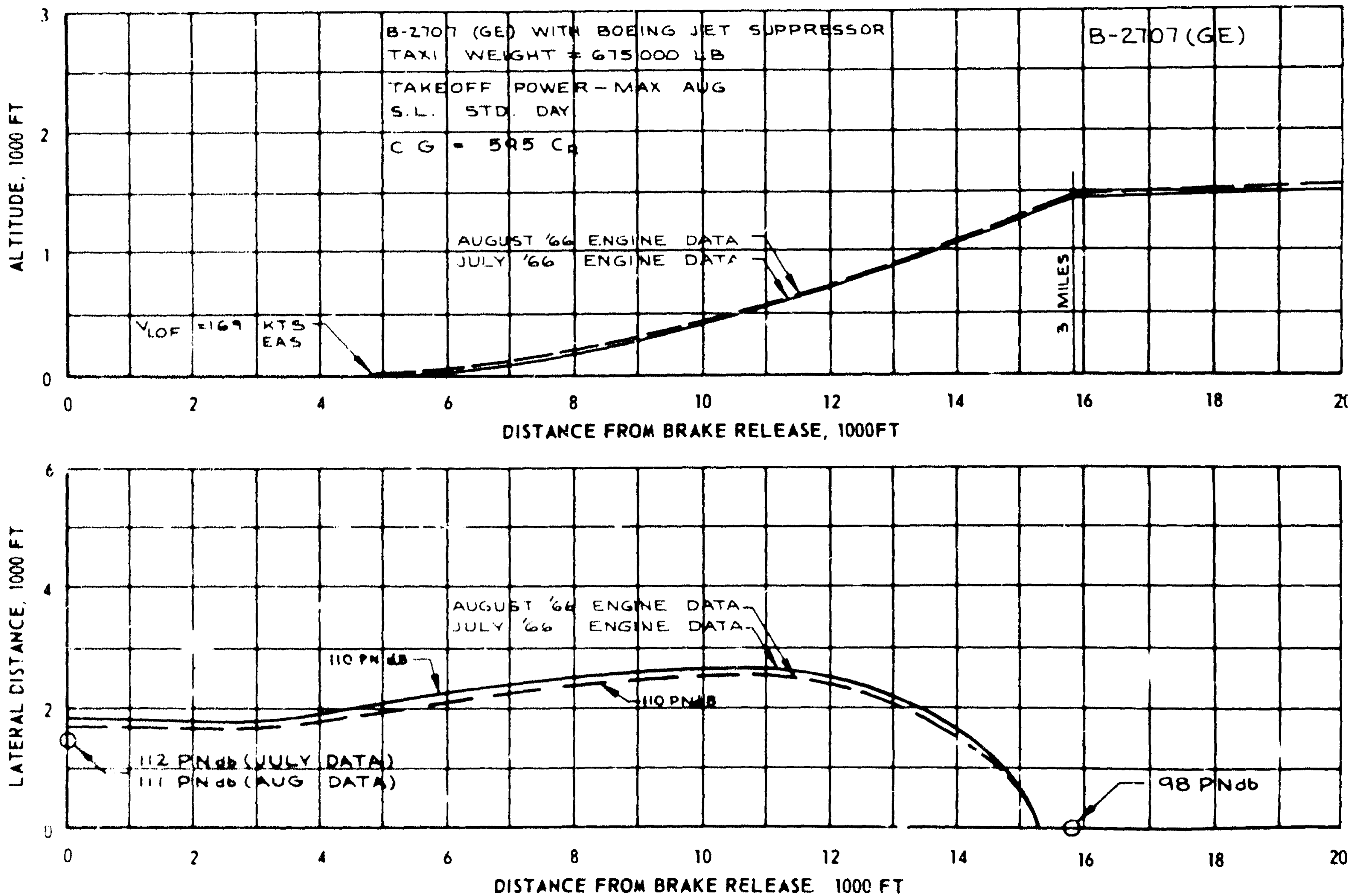


Figure 4-16. Noise Contours, Boeing Jet Suppressor, Model B-2707 (GE)

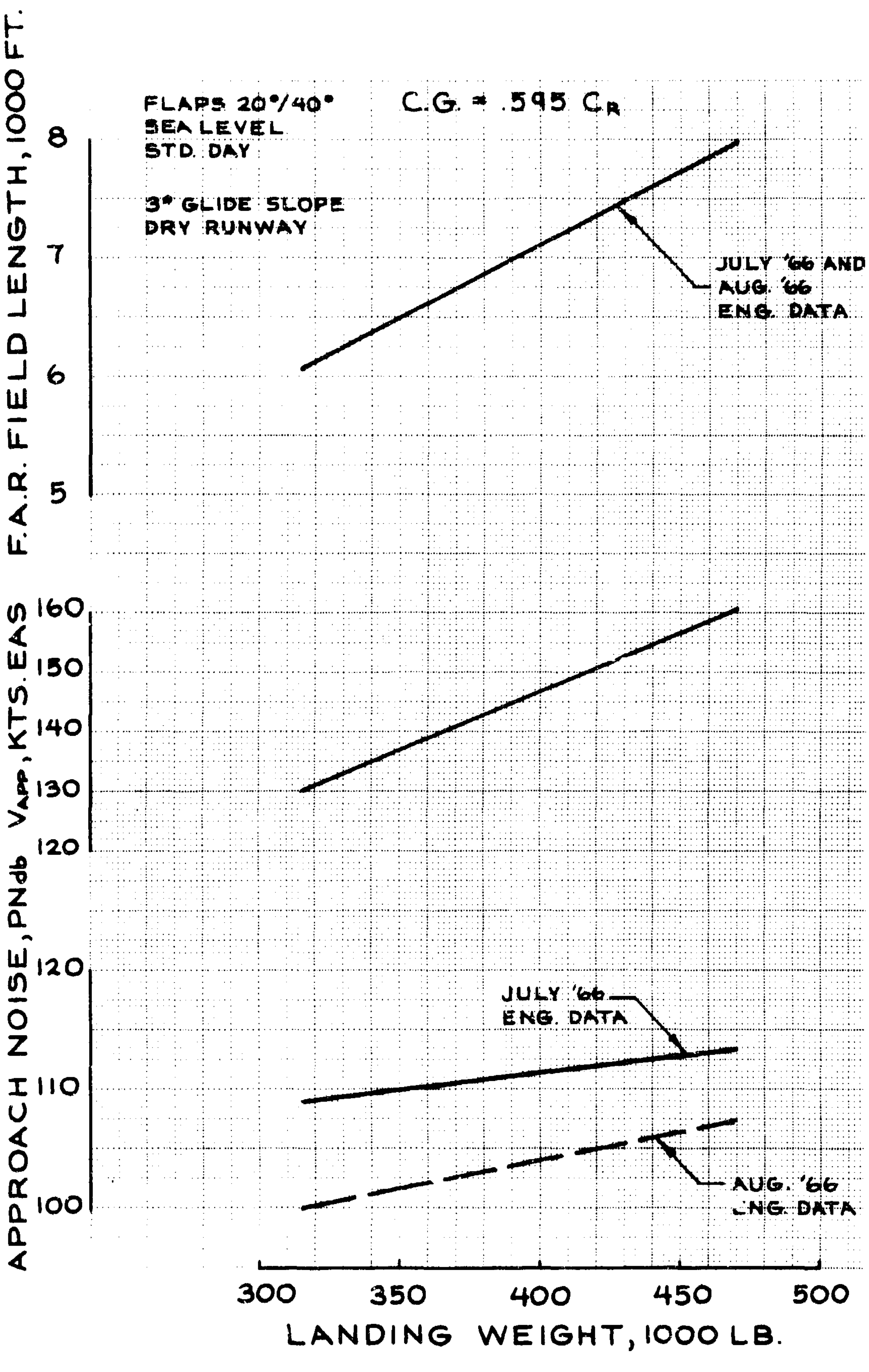


Figure 4-17. Landing Performance Model B-2707 (GE)

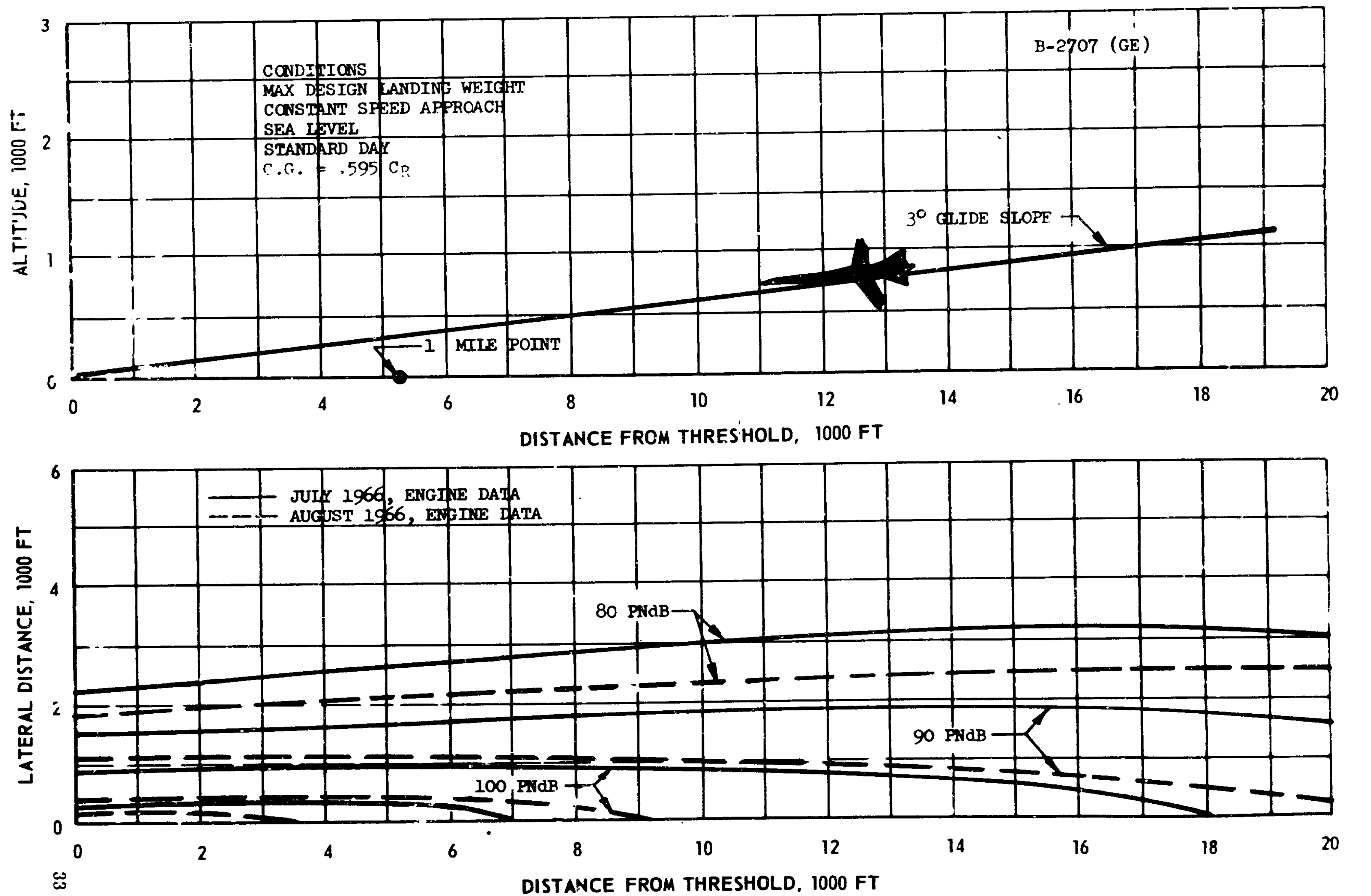


Figure 4-18. Landing Noise Contours, International Mission B-2707 (GE)

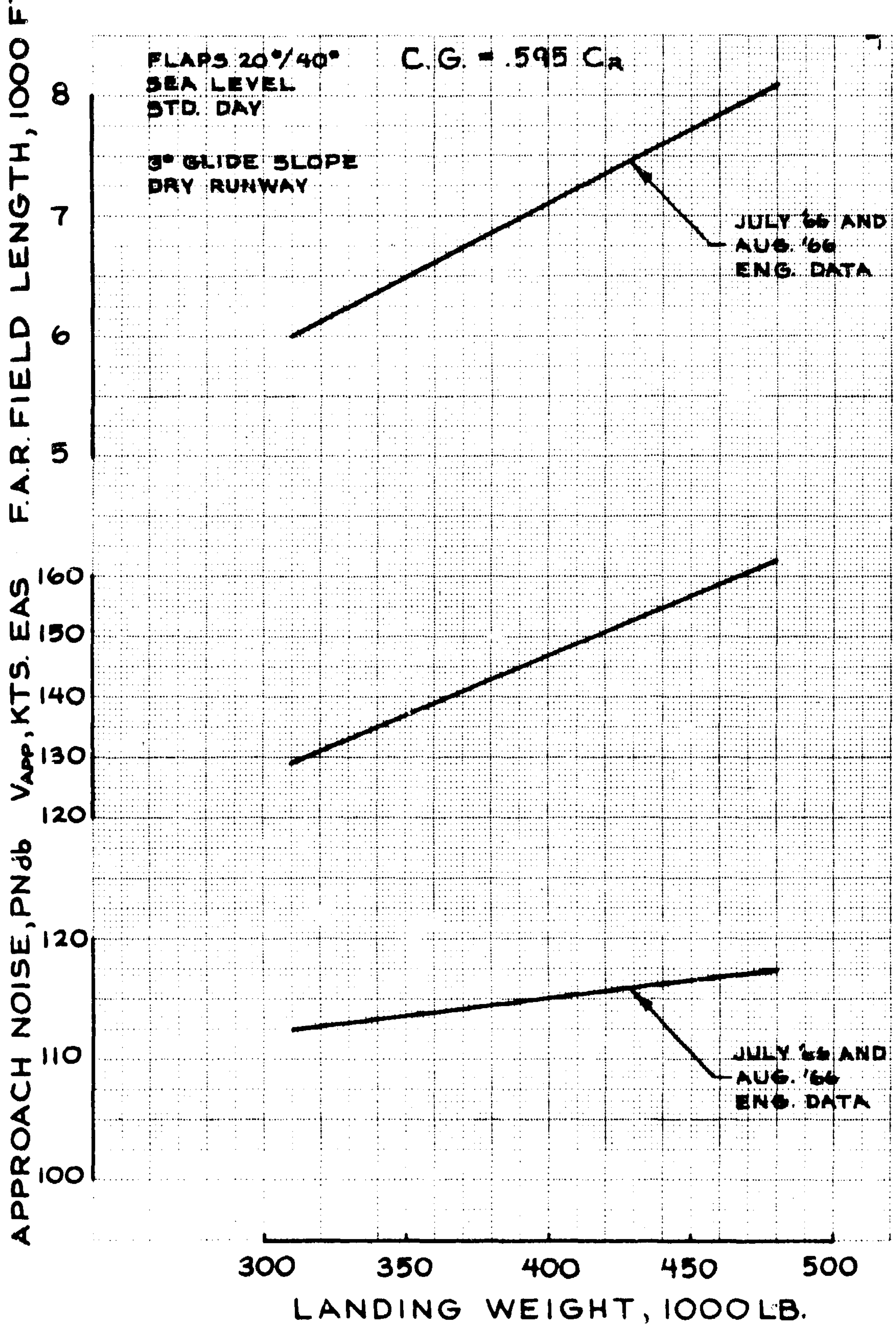


Figure 4-19. Landing Performance Model B-2707 (P&WA)